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AN ASSESSMENT OF BIOSORPTION ACTIVATED MEDIA FOR THE REMOVAL OF POLLUTANTS IN UPFLOW STORMWATER TREATMENT SYSTEMS

by

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A dissertation submitted in partial fulfillment of the requirements
for the degree of Doctor of Philosophy in Environmental Engineering
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at the University of Central Florida
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ABSTRACT

Nitrogen and phosphorus are often the limiting nutrients for marine and freshwater systems respectively. Additionally, stormwater often contains elevated levels of pathogens which can pollute the receiving water body and impact reuse applications [1-4]. The reduction of limiting nutrients and pathogens is a common primary target for stormwater best management practices (BMPs) [5]. Traditional BMPs, such as retention/detention treatment ponds require large footprints and may not be practical in ultra-urban environments where above ground space is limited. Upflow filters utilizing biosorption activated media (BAM) that can be placed underground offer a small footprint alternative. Additionally, BAM upflow filters can be installed at the discharge point of traditional stormwater ponds to provide further treatment. This research simulated stormwater that had already been treated for solids removal; thus, most of the nutrients and solids in the influent were assumed to be as non-settable suspended solids or dissolved solids.

Three different BAM mixtures in an upflow filter configuration were compared for the parameters of nitrogen, phosphorus, total coliform, E. coli, and heterotrophic plate count (HPC). Additionally, genetic testing was conducted using Polymerase Chain Reaction (PCR), in conjunction with a nitrogen mass balance, to determine if Anammox was a significant player in the nitrogen removal. The columns were run at both 22-minute and 220-minute Empty Bed Contact Times (EBCTs).

All the BAM mixtures analyzed were shown to be capable at the removal of nitrogen, phosphorus, and total coliform during both the 22-minute and 220-minute EBCTs, with BAM #1 having the highest removal performance for all three parameters during both EBCTs. All BAM

mixtures experienced an increase in HPC. Additionally, PCR analysis confirmed the presence of Anammox in the biofilm and via mass balance it was determined that the biological nitrogen removal was due to Anammox and endogenous denitrification with Anammox being a significant mechanism.

Dedicated to Rachel, my loving and extremely understanding fiancé.

Thank you for sticking with me through this.

ACKNOWLEDGMENTS

I would like to thank my Ph. D. advisor Dr. Randall, a well as Dr. Martin Wanielista, Dr. Manoj Chopra, Dr. Sean More, and Dr. Andrew O'Reilly for serving on my Ph.D. committee and their guidance throughout my academic career. I would especially like to thank Dr. Moore for the use of his lab and assistance.

I would also like to thank Mike Hardin and all of my colleagues at the UCF Stormwater Management Academy for their help and support in the completion of this dissertation.

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ABBREVIATIONS

AASHTO	American Association of Highway and Transportation Officials
AOB	Ammonia Oxidizing Bacteria (1st part of nitrification)
ASTM	American Society for Testing and Materials
B&G™	Bold & Gold™
BAM	Biosorption activated media
D_{10}	Effective Size: Particle diameter corresponding to 10% finer by mass on the particle distribution curve
D_{15}	Particle diameter corresponding to 15% finer by mass on the particle distribution curve. Common parameter when using soil for a filter.
D_{30}	Particle diameter corresponding to 30% finer by mass on the particle distribution curve
D_{60}	Particle diameter corresponding to 60% finer by mass on the particle distribution curve
D_{85}	Particle diameter corresponding to 85% finer by mass on the particle distribution curve. Common parameter when using soil for a filter.
DNA	Deoxyribonucleic Acid
e	Void ratio
F.A.C.	Florida Administrative Code
FDEP	Florida Department of Environmental Protection
FDOT	Florida Department of Transportation
FS	Factor of Safety
HPC	Heterotrophic Plate Count

$H_2PO_4^-$	Dihydrogen orthophosphate
H_3PO_4	Trihydrogen orthophosphate
HAB	Harmful algal blooms
HPO_4^{2-}	Monohydrogen orthophosphate
k	Coefficient of permeability
K_{vu}	Unsaturated vertical hydraulic conductivity
N	Nitrogen
NELAC	National Environmental Laboratory Accreditation Conference
NH_3	Ammonia
NH_4^+	Ammonium
NO_2^-	Nitrite
NO_3^-	Nitrate
NOAA	National Oceanic and Atmospheric Administration
NOB	Nitrite Oxidizing Bacteria (2nd part of nitrification)
NSQD	National Stormwater Quality Database
NTU	Nephelometric Turbidity Units
OP	Ortho-Phosphorus
OD	Oxygen Demand
P	Phosphorus
PCR	Polymerase Chain Reaction
PO_4^{3-}	Orthophosphate
SRP	Soluble Reactive Phosphorus
TDS	Total Dissolved Solids

TKN	Total Kjeldahl Nitrogen
TMDL	Total maximum daily load
TN	Total Nitrogen
TOC	Total Organic Carbon
TOCD	Total Organic Carbon Demand
TP	Total Phosphorus
TSS	Total Suspended Solids
U.S. EPA	United States Environmental Protection Agency
UCF	University of Central Florida

CHAPTER 1: INTRODUCTION

The building of stormwater treatment systems can be challenging in all types of watershed conditions. Where there are adequate space and elevation differences, designing roadways with stormwater treatment Best Management Practices (BMPs) is relatively straightforward. However, finding a solution that meets multiple criteria is especially difficult in the densely populated ultra-urban environment. Limited aboveground space in the ultra-urban environments complicates the construction of stormwater facilities that implement best management practices (BMP). In ultra-urban areas where space limitations make traditional above ground stormwater BMPs, such as stormwater ponds, impractical biosorption activated media (BAM) upflow filters are an option. Additionally, BAM upflow filters can be installed at the discharge point of stormwater ponds to provide further treatment.

In an ultra-urban environment, the use of traditional treatment best management practices (BMPs) such as retention/detention basins and swales are constrained by the lack of available surface area. Thus, the term "ultra-urban BMP" is associated with the use of BMPs, sometimes proprietary, that have small footprints and are installed underground.

Problem Statement

Stormwater runoff from roads often has elevated levels of nitrogen and phosphorus [6]. Nitrogen and phosphorus species concentrations are also of importance in watersheds because they are limiting nutrients for plant and algal growth in aquatic systems. Excess nitrogen and phosphorus in surface waters causes eutrophication which can eliminate the beneficial use of the water body.

Nitrate contamination of groundwater is of great concern due to the large number of private drinking water wells that are not monitored or treated. Nitrate is listed by the U.S. EPA as a primary drinking water standard with a maximum contaminant level (MCL) and maximum contaminant level goal (MCLG) of 10 mg/L as nitrogen [7]. The current MCL for nitrate was established to prevent infants from being afflicted with Methemoglobinemia, more commonly known as blue-baby syndrome [7]. Studies have also linked chronic exposure to nitrates at concentrations below the MCL to cancer, diabetes, spontaneous abortions, and birth defects [8].

Typically, the primary limiting nutrient for plant and algal growth in freshwater systems is phosphorus and in marine ecosystems it is nitrogen [5]. An excess of limiting nutrients is a major factor in eutrophication. Eutrophication is defined by the United States Environmental Protection Agency (U.S. EPA) as the increase and accumulation of primary producer biomass in a water body through time [9]. According to the National Oceanic and Atmospheric Administration (NOAA) the most common single factor causing eutrophication is an increase in the concentrations of nitrogen and phosphorus species [10].

A common type of eutrophication is harmful algal blooms (HABs). HABs occur in both fresh water and marine environments and are caused by several different algal species including dinoflagellates, diatoms, and cyanobacteria [11]. HABs can have devastating effects on ecosystem integrity, species interactions, aquatic animal health and population growth, human health, economy, industry, and ecology [12]. HABs cause two general types of problems, production of toxins and depletion of dissolved oxygen.

Two well-known examples of the toxic effects of HABs are red tide and blue-green algae blooms. Toxins produced by HABs are responsible for fish and shellfish kills, cattle illness, and respiratory irritation and neurocognitive disease in humans. Additionally, the bioaccumulation of these toxins in aquatic species can lead to diseases such as shellfish poisoning and ciguatera in human consumers [12]. Cyanobacteria are known to produce tumor promoting biotoxins which have resulted in diseases in fish, shellfish, crustaceans, turtles, marine mammals, and other aquatic life [12]. An additional concern is surface water that is a drinking water source. Not all surface water plants are equipped to treat these toxins and the ones that are may not be able to handle the large spikes in toxin concentrations due to the HABs [13].

HABs can also result in water bodies becoming depleted in oxygen or hypoxic. This can occur via several different methods or combination thereof. Thick blankets of algae on the water's surface will block the sunlight from reaching underwater plants, thus causing the water body to become hypoxic [11]. Another method is nitrification; excess inorganic nitrogen loads, either due to stormwater influent or algal die off, cause a population increase in nitrifying bacteria and as a result a significant amount of oxygen is consumed. Hypoxia can also occur when the biomass of algae is so great that the amount of oxygen produced during the day via photosynthesis is less than the nocturnal consumption of oxygen when respiration is greater than photosynthesis [10].

The practical implementation for stormwater treatment is governed by regulations requiring net improvement of the receiving water body which implies a reduction of a target water quality parameter, which in many cases is a nutrient species. Also, the Total Maximum Daily Load (TMDL) restrictions generally target the removal of a nutrient.

Objective

The overall objective of this research project was to develop a bench scale upflow filtration system that utilizes biosorption activated media (BAM) for the treatment of urban stormwater runoff with the goal of improving the water quality of the runoff with specific focus on removal of nitrogen and phosphorus and pathogen reduction. Three different BAM mixtures were evaluated at both an Empty Bed Contact Time (EBCT) of 22 minutes and 220 minutes. The short and long EBCTs simulated systems without and with attenuation. The long EBCT also simulated treatment systems with no attenuation that experience a long duration, low intensity storm event or continuous low flow rate baseflow. An example of an attenuated upflow filter stormwater treatment system would be an underground vault that stores the water during the storm event and allows for a controlled discharge through the upflow filter, thus enabling a longer EBCT.

An ideal implementation of an upflow BAM filter system would be after the stormwater has already been treated by a solids removal system such as a baffle box, vortex separator, or stormwater pond. The removal of solids prior to entering the BAM upflow filter will prevent clogging thus extending the service life. This research simulated stormwater that had already been treated for solids removal by obtaining the simulated stormwater from a stormwater pond. Thus, most of the nutrients and solids in the simulated stormwater influent were as non-settable suspended solids or dissolved solids.

Furthermore, stormwater often has relatively low organic carbon concentrations, compared to domestic wastewater, which is needed for chemoheterotrophic denitrification (commonly used in domestic wastewater plants). The average total organic carbon (TOC) concentrations for freeway runoff and medium domestic wastewater are 9.13 mg/L as C and 140 mg/L as C respectively [14, 15]. Since low organic carbon concentrations are common in stormwater, it is of great interest to determine if Anammox bacteria are present in the system since they are capable of non-chemoheterotrophic nitrogen removal. Polymerase chain reaction (PCR) was utilized to determine if Anammox was present in the BAM mixtures. Nitrogen transformations and removal were analyzed to determine how much of the removal was due to chemoheterotrophic denitrification utilizing influent organic substrate, endogenous denitrification, physical filtration and sorption, and Anammox.

Hypotheses

- BAM #1 will have the highest permeability due to having the largest fraction of the largest diameter media (3/8 inch expanded clay).
- Nitrification and denitrification will be achieved in all three BAM mixtures.
- Chemoheterotrophic denitrification utilizing influent organic substrate will be minimal.
- Nitrogen removal will be dominantly due to biological processes.
- Phosphorus removal will be accomplished by all three BAM mixtures.

Limitations

The simulated stormwater runoff is obtained by spiking stormwater pond water with ammonium carbonate, potassium nitrate, and potassium phosphate in order to approximately reach the average highway runoff concentrations for nitrogen and phosphorus species listed in the National Stormwater Quality Database (NSQD). However, other constituents of the prepared influent may not match the average highway concentrations; this may result in competitive adsorption or other removal mechanisms in the media. The reason why the NSQD values for highway runoff were chosen as the target concentrations for the simulated stormwater runoff is because highways runoff pollutants come from atmospheric deposition, combustion of automotive fuel, and other pollutants associated with vehicle use in the area. These should be approximately the same sources of pollutants in an ultra-urban setting.

Average values of the nitrogen and phosphorus concentrations were obtained for the stormwater pond from which the highway runoff water was simulated. These values were used to determine the masses of chemical spiking required so that the nitrogen and phosphorus concentrations resembled the National Stormwater Quality Database values. The stormwater pond nutrient concentrations vary over time however, so the initial concentrations of influent for each test were not identical, but neither are stormwater runoff concentrations over time.

Roadmap

Examples of detrimental effects resulting from excess nutrient loadings in stormwater are presented in Chapter One, along with the research problem statement, objective, hypotheses, and limitations. Chapter Two contains background information and includes information on the sources of nitrogen and phosphorus in highway runoff, bio-treatment systems, sorption, and filtration. In Chapters Three, Four, and Five there are discussions of results and conclusions of various aspects of the project. Chapter Six is the overall conclusions of the project and proposed future work.

CHAPTER 2: LITERATURE REVIEW

A Definition of Ultra-Urban Environments

Where there are adequate space and elevation differences, retrofitting highways with stormwater treatment Best Management Practices (BMPs) is relatively straightforward. However, initial construction and/or retrofit of stormwater facilities located in dense urban areas can be particularly costly and difficult due to space limitation, high pollutant loadings, high peak flows, traffic management, and utility conflicts. In addition, regulatory requirements may limit the solution for water quality and erosion control issues. Consequently, government agencies and private firms potentially face costly and challenging solutions to pollutant reduction in ultra-urban environments.

The first use of the term ultra-urban environment was most likely by city staff in Alexandria, Virginia [16]. In an ultra-urban environment, the use of traditional treatment BMPs such as detention basins and swales are constrained by the lack of available surface area. Thus, the term "ultra-urban BMP" is associated with the use of BMPs, sometimes proprietary, that have small footprints and are frequently installed underground.

Highway Runoff Pollutants

Stormwater runoff from highways is a source of pollution to surface water bodies and groundwater; pollutants contained in stormwater can lead to environmental problems such as harmful algal blooms and human health problems such as Methemoglobinemia, more commonly known as blue-baby syndrome [7, 11]. Pollutants in highway runoff have several sources including wet and dry deposition, vehicle exhausts, vehicle wear, roadway wear, and accidents [17]. Table 1 shows the average concentrations of some pollutants found in freeway runoff according to the National Stormwater Quality Database (NSQD) and Florida highway runoff according to the Florida Runoff Concentration Database.

Table 1: Average Concentrations of Pollutants in Freeway Runoff from the NSQD [18] and Florida Highway Runoff [19]

Pollutant	National Freeway Runoff Concentrations	Florida Highway Runoff Concentrations
NH_3	1.07 mg/L as N	na
TKN	2.0 mg/L as N	na
$NO_2^- + NO_3^-$	0.28 mg/L as N	na
Total Nitrogen	2.28 mg/L as N	1.37 mg/L as N
Filtered Phosphorus	0.20 mg/L as P	na
Total Phosphorus	0.25 mg/L as P	0.167 mg/L as P
pH	7.10	na
Total Suspended Solids (TSS)	99.0 mg/L	na

Media Filters

Media filters use select materials to remove particulate matter and particulate bound chemicals by straining of the water flow stream. If a sorption material is used in the filter, additional dissolved pollutant removal can be expected. Bacterial biological processes can also be utilized for treatment in media filters. Media filters are different from retention or infiltration basins because the discharge from the media filter is to surface outfalls. Media filtration systems are designed with little or no vegetation, while rain gardens, retention basins, and bioretention areas typically have plants in addition to some form of media.

Typical components of a media filter are collection and distribution structures, pretreatment areas to remove gross solids, media filtration beds, effluent collection systems such as underdrains or upflow channels, and discharge structures to surface outfalls. The filtration bed is usually designed to filter a certain size of particle as well as to remove a target amount of dissolved material.

Media filters are very suitable and applicable to ultra-urban retrofit applications because they can remove significant levels of sediments, particulate-bound pollutants (metals, phosphorus) and organics (oil and grease), and they include designs that are amenable to ultra-urban constraints such as linear configurations and underground installations.

The location of a media filter relative to the transport pipe can be either off-line or on-line. Both designs must consider a provision for bypass of water when the flow is in excess of the treatment rate. To attain a specified treatment rate, head differential or head loss must be considered. Typically, the design rate of filtration has been greater than or equal to 0.25 inches/hour because of cost and space limitations [20].

The options for media filtration can be divided into two broad categories:

- Sand filter systems
- Mixed media systems

Sand filters remove most of the particulate fraction but typically do not remove dissolved pollutants. Sorption based media as part of a mixed media improves the removal of dissolved pollutants. Both sand and mixed media systems can also be utilized for biological treatment processes as well.

Another distinction in design is the direction of flow, either a down flow or an upflow design. The down flow filters are common and simple but have to be maintained more frequently because of a build-up of solids on the filter surface. While the upflow filter is cleaned or replaced less frequently because solids are distributed more uniformly throughout media due to fluidization of the media during upflow. It may be desirable to precede upflow and downflow filtration systems with a large particle removal system such as s sedimentation pond, baffle box, or vortex separator. These processes remove large particles that contribute to clogging, thus potentially increasing the life span of the filter.

Sand Filter Systems

A sand filter is composed of graded sand and typically follows some type of sedimentation and debris separation system. The sand filter removes most particulates of a certain size. It is usually 2 feet deep. Locally available sandy media are preferred but, in some designs, the size distribution is specified. A summary of early designs and performance is available in a government fact sheet [21]. California [22], Texas [23], Massachusetts [24], and Delaware (www.deldot.gov) are example areas where sand filters are used and in regulation.

Mixed Media Systems

As the name implies, there are at least two different types of media which are blended to achieve specified pollutant removal effectiveness. The media may include, but are not limited to, sawdust, peat, compost, zeolite, wheat straw, newspaper, sand, limestone, expanded clay, clay, zero-valent iron, wood chips, wood fibers, mulch, glass, ash, pumice, bentonite, tire crumb, expanded shale, oyster shell, and soy meal hull. Thus, there is a wide selection of media mixtures that have been tested and are used in media filtration systems [25].

Media mixtures that are effective for removing a wide range of pollutant types are sand/clay with other additions [26], as well as expanded clay with other media [27, 28]. Some mixes target specific pollutants, such as used by the Washington State DOT whose mix targets dissolved metals [29], and media mixes that target phosphorus [30], nitrate [31], phosphorus and nitrogen [32], organics [33], and metals and dioxins [34].

There are blends of sorption media on the market that will accomplish removal of dissolved pollution. Research needs to be conducted to determine the life expectancy of the media's removal mechanism. A biological removal mechanism that does not destroy the organisms is the most preferable mechanism because of the long-life expectancy. Such biological removal media are Biosorption Activated Media (BAM). However, all pollutants cannot be removed effectively by biological means and thus, whatever mechanism is used for the removal of dissolved pollution has to be documented to determine life expectancy of the removal mechanism for all targeted pollutants.

Removal Mechanisms in upflow BAM systems

As stormwater upflows through the filtration system pollutants are removed via the abiotic processes of sedimentation, depth filtration, precipitation, adsorption, and ion exchange; as well as the biological mechanism of biosorption/biological uptake. An extensive discussion of these processes with respect to BAM can be found in Hood [35].

Biological uptake of Nitrogen

Biosorption is the sorption of nutrients onto the cellular surfaces of the biomass or biofilm and is considered an abiotic process [36, 37]. Biological uptake involves the transport of biosorbed pollutants from the cellular surfaces of the biomass into the interior of the cell, mainly by energy-consuming active transport [37]. Biological uptake is accomplished via microbial-mediated transformations, such as nitrification, chemoheterotrophic denitrification, Anammox (anaerobic ammonium oxidation), and biological assimilation (also known as synthesis or growth). It is assumed that the BAM upflow filter will reach a steady state condition where the biofilm growth rate is approximately equal to the rate at which biofilm is sloughed off. The sloughed biofilm can either exit the system in the effluent or may be retained via sorption and filtration processes.

Nitrification & Denitrification

Nitrification

Nitrifying bacteria are classified as aerobic chemoautotrophs. Nitrification is a two-step, energy-yielding reaction that occurs under aerobic conditions. Nitrification results in the oxidation of ammonia to nitrate. The first step is the conversion of ammonia to nitrite by nitroso-bacteria, also known as ammonia-oxidizing bacteria (AOB). This is followed by the conversion of nitrite to nitrate by nitro-bacteria, also known as nitrite-oxidizing bacteria (NOB) [38, 39].

Chemoheterotrophic Denitrification

Chemoheterotrophic denitrification occurs under anoxic conditions and involves the oxidation of organic carbon using nitrate or nitrite as the electron acceptor [38]. Anoxic conditions are defined as DO levels below 0.2 mg/L; DO levels above 0.2 mg/L can inhibit denitrification [38, 40]. The result is the reduction of nitrate or nitrite to gaseous forms of nitrogen: nitric oxide, nitrous oxide, and dinitrogen gas. Under anoxic conditions the end product is dinitrogen gas; however under fluctuating oxygen levels nitric oxide and nitrous oxide often form [41].

If organic carbon is not available in sufficient quantities in the influent substrate, endogenous chemoheterotrophic denitrification can occur. Endogenous denitrification occurs when cells breakdown, making their carbon biologically available to intact heterotrophic bacteria [38, 42].

Denitrification bacteria are typically chemoheterotrophs, however chemoautotrophic denitrifiers exist. Most of the bacteria responsible for denitrification are facultative aerobic, meaning that oxygen is the preferred electron accepter but under anoxic conditions they will utilize nitrate or nitrite as an electron acceptor [38].

Denitrification via Facultative Aerobic Chemoautotrophs

A facultative aerobic bacteria is one which prefers to use oxygen as the electron acceptor when it is present, however in the absence of oxygen these bacteria are capable of using an alternative electron acceptor such as nitrite or nitrate. The facultative aerobic chemoautotophic nitrifying bacteria *Nitrosomonas europaea* is such an example. Under aerobic conditions this bacteria will oxidize ammonia using oxygen as the electron acceptor. However, under anoxic conditions *Nitrosomonas europaea* is capable of oxidizing ammonia using nitrite as the electron acceptor. When this occurs, nitrite is reduced to nitrogen gas and thus both nitrification and denitrification occur simultaneously. This mechanism is likely a minor one unless under very specific conditions. Under normal anoxic conditions the ammonia oxidation rate by *Nitrosomonas europaea* is 6 to 10 times less than that by Anammox bacteria, which are discussed in detail in the following section [38].

Denitrification via Anammox

Anammox is a chemoautotrophic process performed by bacteria belonging to the phylum *Planctomycete* and more specifically the order *Planctomycetales* [38, 43, 44]. Anammox bacteria are obligate anoxic bacteria, meaning that they cannot utilize oxygen as an electron acceptor. Anammox is a process that creates nitrogen gas by oxidizing ammonium (electron donor) with nitrite (electron acceptor). Nitrite also functions as an electron donor for the reduction of carbon dioxide. The formula for Anammox is shown in Equation (1) [43-45].

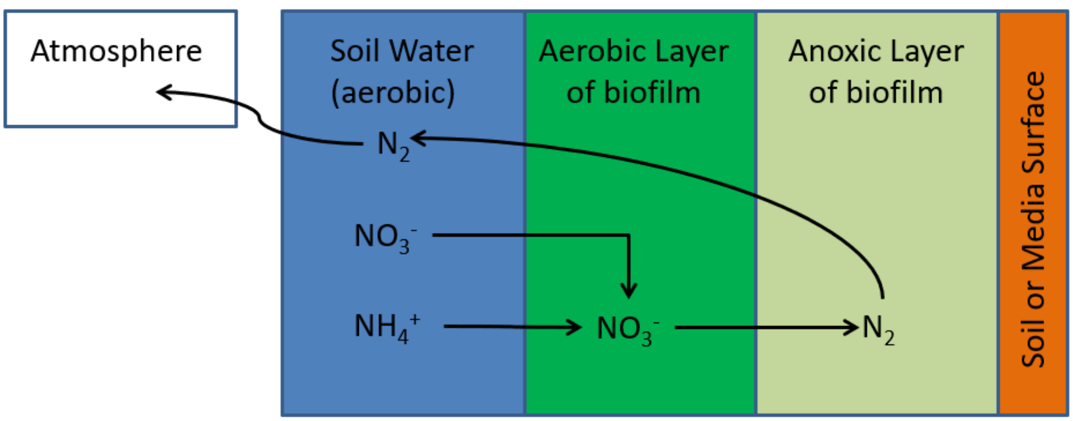
$$NH_4^+ + 1.32\ NO_2^- + 0.066\ HCO_3^- + 0.13\ H^+ \rightarrow 1.02\ N_2 + 0.26\ NO_3^- + 2.03\ H_2O + 0.066\ CH_2O_{0.5}N_{0.15} \qquad (1)$$

Since Anammox utilizes nitrite as an electron acceptor it must be coupled with chemoautotrophic aerobic ammonium-oxidizing bacteria (AOB). However, the presence of nitrite-oxidizing bacteria (NOB), which are also aerobic, is not desirable since they compete with anammox bacteria for the nitrite. The ideal is to have enough oxygen present for AOB to occur but not enough for NOB be present; note that AOB will consume the oxygen 1^{st} since NOB need the nitrite produced by the AOB, just as the Anammox do. This circumstance can be achieved in a carefully controlled reactor or a media fixed biofilm [43, 45].

Simultaneous Nitrification & Chemoheterotrophic Denitrification in Biofilm

Nitrification and chemoheterotrophic denitrification can occur simultaneously in a region of the upflow BAM filter that is considered to be under aerobic conditions due to the structure of the biofilm itself. As the biofilm grows and becomes well established, its thickness will increase. As the thickness of the biofilm increases, oxygen is consumed faster than it can diffuse throughout the entire depth of the biofilm; as a result the biofilm is composed of an inner anoxic layer and an outer aerobic layer [38, 46]. Nitrification in the outer aerobic layer transforms ammonia into nitrate which then diffuses into the inner anoxic zone where it undergoes chemoheterotrophic denitrification, as illustrated in Figure 1. Nitrate in the soil water may also defuse through the biofilm layers to the anoxic zone, where it to can undergo chemoheterotrophic denitrification.

It is worth noting that if the biofilm gets too thick then the substrate will not be able to reach the inner anoxic layer. Without a substrate provided organic carbon source for denitrification the heterotrophic bacteria may enter an endogenous respiration state and lose their ability to cling to the media surface. This will result in the biofilm sloughing off the media [47].



Note: Organic carbon source not shown, may be either organic substrate or endogenous.

Figure 1: Chemoheterotrophic Denitrification in the Biofilm

Simultaneous Nitrification & Chemoautotrophic Denitrification via Anammox in Biofilm

Anammox can occur in a biofilm due to the aerobic-anoxic interface that occurs [42, 45]. The outer layer of the biofilm will exist in the aerobic zone but the inner layers of the biofilm will be devoid of oxygen. The AOB will take priority over the NOB for oxygen consumption and thus will inhabit the external aerobic surface of the biofilm. Furthermore, the inner anoxic layer may also be devoid of organic carbon containing substrate due to the difficulty of diffusing substrate through the biofilm [42, 45]. The inner anoxic layer of the biofilm may either be undergoing endogenous denitrification, which would possibly lead to sloughing of the biofilm due to needing organic carbon, or autotrophic Anammox, which does need ammonia and nitrite but does not need organic carbon and may not result in sloughing [45]. The aerobic-anoxic interface and the process of Anammox in biofilm is illustrated Figure 2.

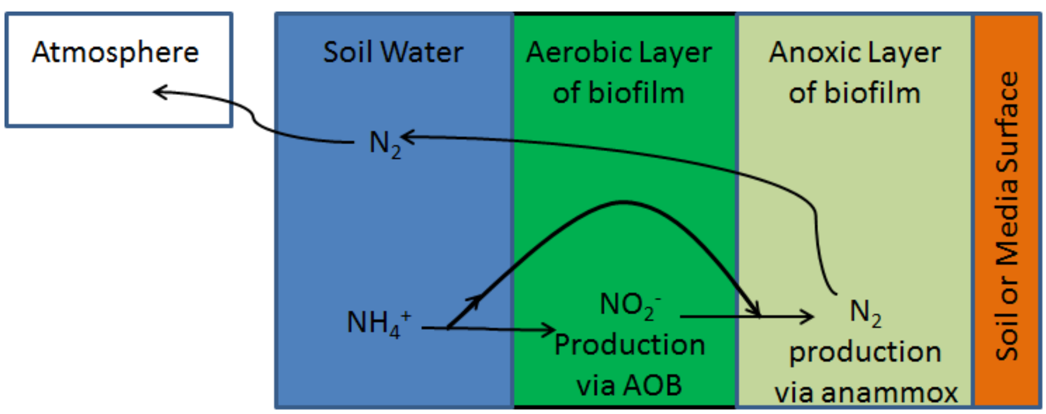


Figure 2: Anammox in Biofilm

Bold & Gold™

Bold & Gold™ is a Biosorption Activated Media (BAM) developed by the University of Central Florida Stormwater Management Academy. BAM is designed for four purposes: high permeability, inert filtration, reactive filtration, and to provide an ideal habitat for microbes. Previous research involving Bold & Gold™ is found in Hood [48] and Chang [25].

Bold & Gold™ Components

The various Bold & Gold™ media mixtures analyzed in this project contain 50/50 ratio course and fine expanded clay (hence forth referred to as 50/50 expanded clay), ⅜-inch expanded clay, automobile tire crumb (1–5 mm), limestone screenings, and AASHTO (American Association of State Highway and Transportation Officials) classification A-3 sand with 1.8% silt/clay and A-3 sand with 7.1% silt/clay. The limestone screenings had an approximate D_{15} and D_{85} of 2.3 mm and 12 mm respectively. D_{15} and D_{85} are the diameters corresponding to 15% and 85% finer by mass when conducting a sieve analysis (see Figure 44) [49, 50]. D_{15} and D_{85} are specifications commonly used in the design of media filters [50]. See APPENDIX I for a brief explanation of the AASHTO soil classification system and sieve analyses of the BAM types.

Tire Crumb

Automobile tires are generally composed of 27% to 33% carbon black by mass; carbon black functions similarly to activated carbon [51]. Activated carbon has a large surface area to mass ratio, which makes it ideal for adsorption [52]. Activated carbon is very effective in removing large organic molecules and non-polar compounds [52].

Additionally, activated carbon and tire crumb have been utilized to remove ammonia via ion exchange and sorption, although efficiency of this process has a wide range of reported results [51, 53, 54]. Activated carbon has also been shown to be effective at removing ortho-phosphorus over a range of 3 to 10 pH; thus freeway runoff, at an average 7.10 pH should be readily removed by activated carbon and BAM [18, 55-57].

NOx is a highly soluble and stable ion and does not readily sorb [58]. The average pH range for stormwater, 7.0 to 8.1, is not an effective pH range for NOx sorption onto activated carbon and likely BAM since tire crumb behaves as activated carbon [14, 59].

Clay

Clay minerals are aluminum silicates composed of silica tetrahedrons and alumina octahedrons. Clay particles have a net negative charge on the surfaces due to negatively charged functional groups. This net negative charge is balanced by exchangeable cations such as Ca^{2+}, Mg^{2+}, Na^{+}, and K^{+}. Additionally, there are some positively charged functional groups located on the edges of the clay particles [60]. These properties make clay an ideal adsorption media.

The average pH of freeway runoff is 7.10; at this pH the dominant form of aqueous ammonia present is ammonium (NH_4^+) [18, 61]. As mentioned previously, clay has a net negative charge and is balanced by exchangeable cations such as Ca^{2+}, Mg^{2+}, Na^{+}, and K^{+}. As a result, clay is capable of capturing ammonium via cation exchange [54].

Clays are a commonly used adsorbent and anion exchange media for the removal of phosphorus, principally as phosphate [62]. Phosphate adsorption to clay generally occurs by bonding to the positively charged edges and by anion exchange of phosphates for silicates in the clay [63]. Furthermore, the sorption capacity of clay is increased even further by the process of calcination, which forms expanded clays [64].

Expanded Clay

Expanded clays are typically composed of an inert ceramic particle with a porous coating. Expanded clay is created by a process known as calcination which involves exposing the clay to temperatures of up to 1200°C inside a rotary kiln. During calcination the organic matter in the clay expands resulting in a high porosity, low bulk density aggregate. Furthermore, the expanded clay has a higher hydraulic conductivity (aka permeability) than similarly sized gravels and sands [62]. The phosphorous sorption capacity for expanded clays has been found to range between 0.037 to 2.90 g P/kg, depending on the origin of the clay [65].

The high porosity of expanded clays enables them to maintain a relatively high moisture content even if the media was to become unsubmerged. The combination of consistent high moisture content and large surface area makes the expanded clay an ideal habitat for microbes. In this way expanded clay also contributes to microbial-mediated transformations.

CHAPTER 3: PHOSPHORUS REMOVAL UTILIZING UPFLOW BAM FILTERS FOR THE APPLICATION OF TREATING STORMWATER IN A LOW-FOOTPRINT ULTRA-URBAN ENVIRONMENT

Abstract

Phosphorus is often the limiting nutrient for freshwater systems and thus it's reduction is commonly a primary target for stormwater best management practices (BMPs) [5]. Traditional BMPs, such as retention/detention treatment ponds require large footprints and may not be practical in ultra-urban environments. Upflow filters utilizing biosorption activated media (BAM) that can be placed underground and in line with the stormwater system offer a small footprint alternative. This paper compares three different BAM mixtures in a bench scale, upflow filter configuration for the parameters of permeability, total phosphorus, soluble reactive phosphorus, and total suspended solids. This research simulated stormwater that had already been treated for solids removal; thus, the phosphorus in the influent was assumed to be mostly non-settable suspended solids or dissolved. The columns were run at both 22-minute and 220-minute Empty Bed Contact Time (EBCT). The BAM compositions studied are composed of various ratios of limestone screenings, (American Association of State Highway and Transportation Officials) classification A-3 sand with 1.8% silt/clay and A-3 sand with 7.1% fines, 50/50 ratio course and fine expanded clay, 3/8 inch expanded clay, and tire crumb. An unexpected result of this project was that the BAM with the highest permeability constant achieved the best removal efficiency for both total phosphorus and soluble reactive phosphorus, indicating that phosphorus removal was accomplished primarily by sorption and not physical filtration.

Keywords: biosorption activated media; BAM; stormwater; bio-filtration; tire crumb; expanded clay; phosphorus; water quality; sustainability; highway runoff; best management practice; BMP

Introduction

Stormwater runoff often contains elevated levels of the limiting nutrients nitrogen and phosphorus, which according to the National Oceanic and Atmospheric Administration (NOAA) are the most common factors causing eutrophication [6, 10]. Typically, the primary limiting nutrient for plant and algal growth in freshwater systems is phosphorus [5]. Total phosphorus is composed of soluble reactive phosphorus (SRP), particulate reactive phosphorus, dissolved and particulate condensed phosphates (also known as polyphosphates), and dissolved and particulate organic phosphorus, see Figure 3 [43, 61, 66-70]. The designation of non-SRP phosphorus is used in this paper to designate all forms of phosphorus other than SRP since lab analysis was only run for SRP and total phosphorus. Dissolved forms of phosphorus are those that can pass a 0.45 µm filter and include SRP, dissolved polyphosphate, and dissolved organic phosphorus [66]. Phosphorus forms that do not pass a 0.45 µm filter are considered particulate phosphorus and include particulate bound inorganic phosphorus and particulate organic phosphorus [66]. Organic phosphorus is phosphorus existing in a carbon chain and is primarily formed by biological processes as a part of plant or animal tissue [43, 66]. Polyphosphates are used in organisms for storing energy, cell capsule formation, metabolic regulation, and other purposes [38, 43, 61, 71]. Reactive phosphorus is a close approximation for orthophosphate [66].

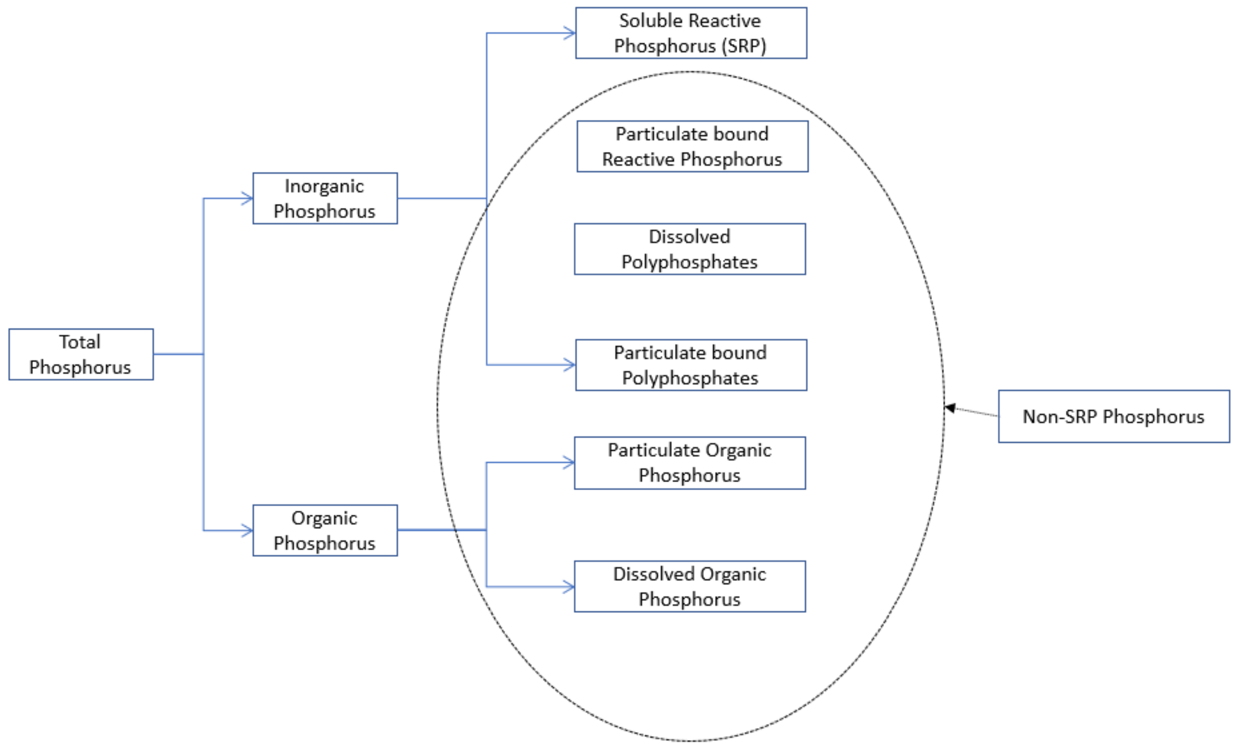


Figure 3: Types of Phosphorus [43, 61, 66-70]

SRP, approximately equal to dissolved ortho-phosphorus, is of particular interest since SRP is the phosphorus species that is readily available to plants and algae for uptake [72, 73]. Phosphorus has historically been removed from stormwater using best management practices (BMPs) such as retention/detention treatment ponds and flocculation, however these methods required a large footprint which is not always feasible in an ultra-urban environment. A possible solution is the use of small footprint, ultra-urban BMPs such as upflow, biosorption activated media (BAM) filters that can be placed underground and in line with the stormwater system.

Downflow filters are commonly utilized in stormwater treatment but are prone to clogging and compaction of the media, leading to reduced flow rates/performance and shorter life spans [74, 75]. Upflow filters are less prone to clogging; between storm events particulate matter that has become trapped on the bottom of the upflow filter will fall away, thus unclogging the filter and maintaining permeability [75]. Additionally, although not necessary for phosphorus removal since phosphorus is removed primarily by adsorption and particulate removal, upflow filters can be designed to allow the media to remain submerged which maintains biofilms which are necessary for the biological removal of nitrogen.

BAM is a material that has been utilized in a variety of stormwater treatment systems [27, 48, 76]. BAM can consist of one or more types of media which are blended to achieve specified pollutant removal effectiveness; there is a wide selection of media mixtures that have been tested and are used in media filtration systems [25]. As stormwater flows through the filtration system pollutants are removed via sedimentation, depth filtration, adsorption, ion exchange, and biosorption/biological uptake. An extensive discussion of these processes with respect to BAM can be found in Hood, 2012 [35].

The BAM in this research is composed of tire crumb, 3/8 inch expanded clay, 50/50 ratio course and fine expanded clay (hence forth referred to as 50/50 expanded clay), limestone screenings, AASHTO (American Association of State Highway and Transportation Officials) classification A-3 sand with 1.8% silt/clay, and AASHTO A-3 sand with 7.1% silt/clay. See APPENDIX I for a brief explanation of the AASHTO soil classification system.

Sand primarily removes phosphorus species through physical filtration of particulate bound phosphorus. Tire crumb, clay, and expanded clay are excellent at sorption of dissolved phosphorus from stormwater and are also capable of removing particulate bound phosphorus via filtration [27, 35, 49, 52, 62-65, 77]. Limestone has also been proven effective at both sorbing and flocculating dissolved phosphorus species [78-81].

Expanded clays are a known sorbent of phosphorus [62, 82]. Expanded clays are typically composed of an inert ceramic particle with a porous coating. Expanded clay is created by a process known as calcination which involves exposing the clay to temperatures of up to 1200°C inside a rotary kiln [62, 83]. During calcination the organic matter in the clay expands resulting in a high porosity, low bulk density aggregate. Furthermore, the expanded clay has a higher hydraulic conductivity (aka permeability) than similarly sized gravels and sands [62]. Scanning electron microscope views of 50/50 expanded clay are shown in Figure 4; note the extremely porous nature of the material.

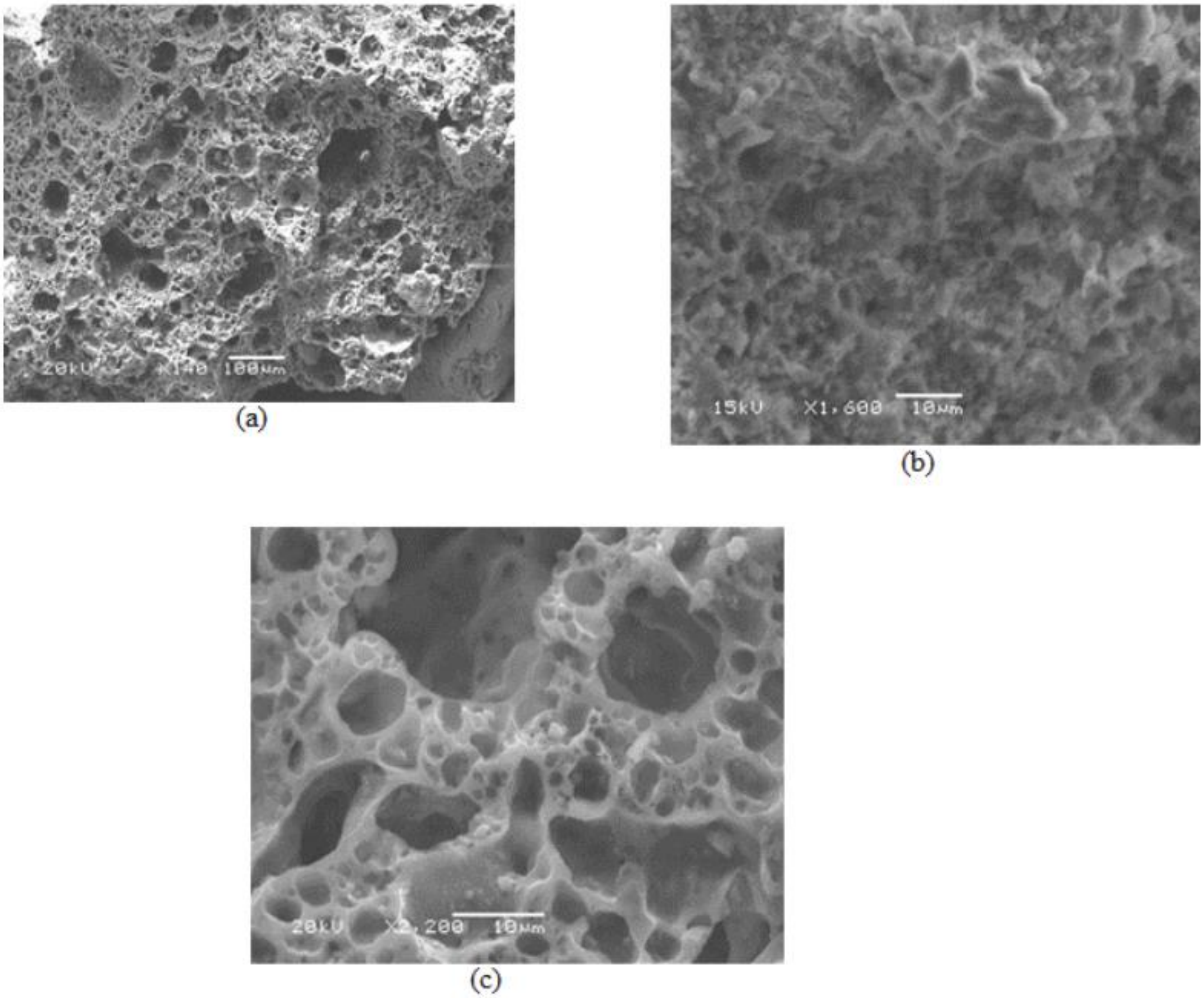


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Figure 4: 50/50 expanded clay shown in Scanning Electron Microscope (a) 140 X, (b) 1,600 X, (c) 2,200 X magnification [84, 85]

An ideal implementation of an upflow BAM filter system would be after the stormwater has already been treated by a solids removal system such as a baffle box, vortex separator, or stormwater pond. The removal of solids prior to entering the BAM upflow filter will prevent clogging thus extending the service life. This research simulated stormwater that had already been treated for solids removal; thus, most of the nutrients and solids in the simulated stormwater influent were likely as non-settable suspended solids or dissolved solids.

The objective of this research was to develop a bench scale upflow filtration system that utilizes BAM to remove phosphorus from urban stormwater. Three different BAM mixtures were evaluated during both 2-hour, high intensity, and 24-hour, low intensity, simulated storm events for soluble reactive phosphorus (SRP), approximately equal to ortho-phosphorus, and total phosphorus removal performances. The 2-hour and 24-hour simulated storm events have Empty Bed Contact Times (EBCTs) of 22 and 220 minutes respectively. The 24-hour simulated storm event, in addition to representing a long, low intensity storm, also simulates a treatment train that has attenuation, thus allowing for a long EBCT. Stormwater attenuation is the storage of stormwater during high flow periods, followed by a controlled release of the stored water, thus reducing the hydrograph peak [86, 87].

Methods

Experimental Design

The experimental design analyzed three types of BAM mixes, which were composed of 50/50 volumetric ratio blend of course and fine expanded clay (hence forth referred to as 50/50 expanded clay), ⅜-inch expanded clay, automobile tire crumb (1-5 mm), limestone, and AASHTO classification A-3 sand with 1.8% silt/clay, and AASHTO A-3 sand with 7.1% silt/clay. Table 2 presents the compositions and of the BAM types analyzed in the experimentation. A brief description of the AASHTO soil classification system as well as particle size distribution curves for the BAM mixes and the individual components can be found in APPENDIX I. The permeability constant, dry density, and dry mass of each BAM type analyzed are presented in Table 3.

Table 2: BAM Compositions

BAM #	50/50 Expanded Clay	3/8 inch Expanded Clay	Tire Crumb	A-3 sand with 1.8% silt/clay	A-3 sand with 7.1% silt/clay	Limestone Screenings
1	55%	20%	25%	0%	0%	0%
2	0%	25%	0%	50%	25%	0%
3	15%	0%	15%	50%	0%	20%

Note: Percentages were as loose, uncompacted volumetric ratios.

Table 3: BAM Characteristics

BAM #	Permeability constant (in/hr)	Dry Density of BAM in Column (kg/m^3)	Dry Mass of BAM in Column (kg)
1	475.25	579.6	2.9
2	6.733	1242.5	6.1
3	12.86	1246.4	6.2

The bench-scale experiment consisted of six columns divided into three sets of two columns each. All the columns had an internal diameter of 4 inches. The media occupied 2 feet of each column, see Figure 5. For identification of the columns, each column had a number and letter designation, of which the number designates the type of media in the column (see Table 2), and the letter designates each of the duplicate columns, A and B. The A and B columns were duplicate columns with a single type of BAM. See APPENDIX N for a more detailed description of the system design.

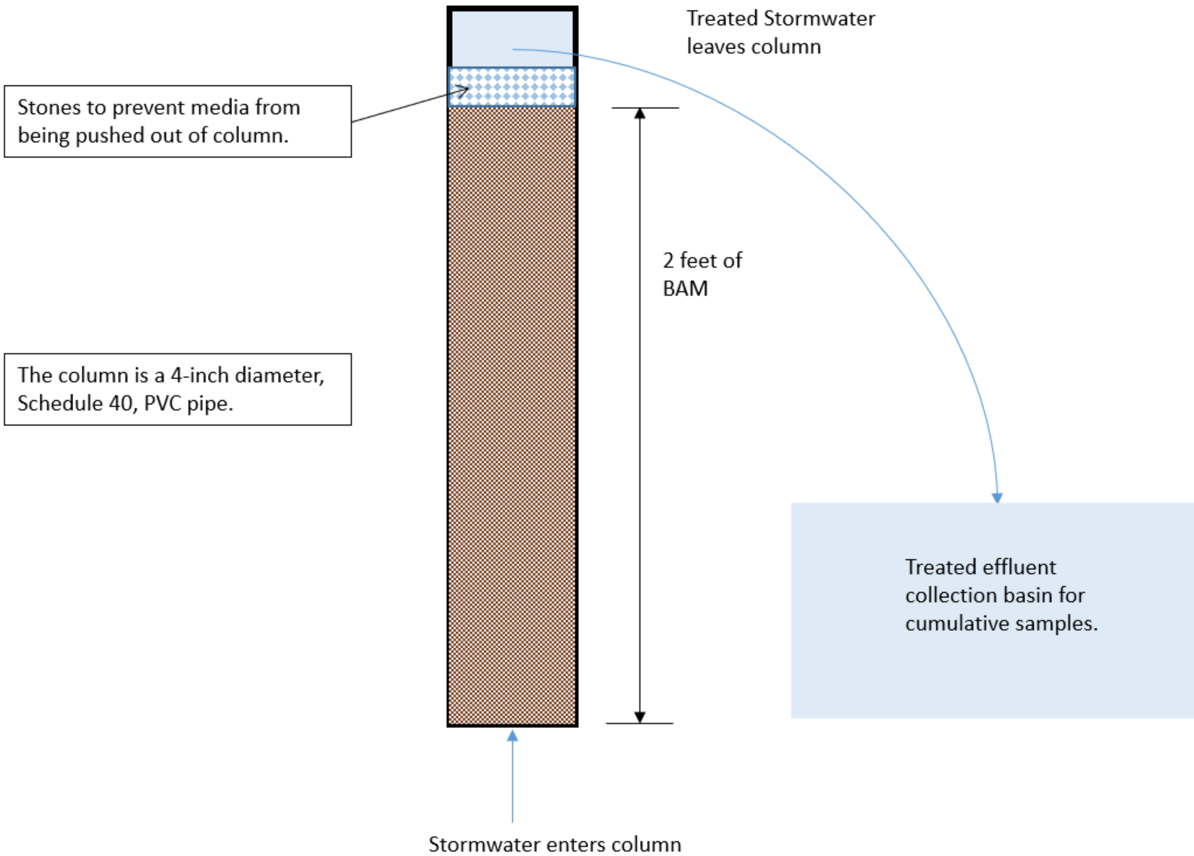


Figure 5: Upflow Column Design

Operation of columns

The simulated stormwater runoff was obtained by spiking stormwater pond water with ammonium carbonate, potassium nitrate, and potassium phosphate in order to approximately reach the average highway runoff concentrations for nitrogen and phosphorus species listed in the National Stormwater Quality Database (NSQD), see Table 1 [18]. Since the simulated stormwater was obtained from a pond, most of the settable solids had already been removed; the

NSQD average TSS for freeway runoff is 99 mg/L whereas the average influent TSS to the BAM columns was 4.75 mg/L and 3.00 mg/L for the 22-minute and 220-minute EBCTs respectively. Additionally, since dissolved forms of nitrogen and phosphorus were used to spike the pond water for nutrient content, it can be assumed that most of the nutrients are either as dissolved or non-settable suspended solids. Thus, the simulated stormwater represents stormwater that had been already treated for solids removal by a baffle box or pond and the remaining nutrient content is mostly as dissolved or non-settable suspended solids. The stormwater characteristics prior to and after spiking are shown in Table 5.

Table 4: Average Concentrations of Pollutants in Freeway Runoff from the NSQD [18]

Pollutant	National Freeway Runoff Concentrations
NH_3	1.07 mg/L as N
TKN	2.0 mg/L as N
$NO_2^- + NO_3^-$	0.28 mg/L as N
Total Nitrogen	2.28 mg/L as N
Filtered Phosphorus	0.20 mg/L as P
Total Phosphorus	0.25 mg/L as P
pH	7.10
Total Suspended Solids (TSS)	99.0 mg/L

Table 5: Characteristics of Stormwater before and after spiking

Units	Parameter	Initial Stormwater Pond Concentration	Average Simulated Stormwater Values (after spiking)
Values in mg/L as N or P	NH_3	0.051	0.684
	$NO_2^- + NO_3^-$	0.04	0.249
	Total Nitrogen	0.669	1.594
	Ortho Phosphorus	0.004	0.187
	Total Phosphorus	0.029	0.221

The column operations simulated 2- and 24-hour simulated storm events. There were three 2-hour storm, high intensity, events per week and one 24-hour, lower intensity, storm event per week. Sampling events occurred twice a week, once for a 2-hour storm event and once for a 24-hour storm event, over a 7 month period.

Based on the dimension for each (a diameter of 4 inches and a height of 24 inches), the total volume was 302 in^3 with a cross-sectional area of 12.57 inches. The empty bed contact time (EBCT) and hydraulic loading rates were calculated from the actual volume of effluent collected from each column. There was little column-to-column variation for the EBCT and hydraulic loading rates for both the 2 and 24-hour rates. The average EBCT and hydraulic loading rates are presented in Table 6.

Table 6: EBCT and Hydraulic Loading Rate

Flow Duration (hours)	EBCT (minutes)	Hydraulic Load per unit volume of BAM "1/hour" (in^3 water / hour) / (in^3 of BAM)	Hydraulic Load per cross -sectional area (aka the flux) (gallons water / minute) / (ft^2 of cross section)
2	22	2.723	0.679
24	220	0.273	0.068

Water sampling

Effluent stormwater from each column was collected as a cumulative sample at the conclusion of the simulated storm event. The effluent and influent water samples were then sent to a NELAC (National Environmental Laboratory Accreditation Conference) certified laboratory for ortho-phosphorus and total phosphorus testing.

Results & Discussion

Soluble Reactive Phosphorus

Data from the duplicate A and B columns was combined to produce a more robust data set for SRP. Box and whisker plots were utilized to identify the median values of the influents and effluents, as well as the outlier; see Figure 6, Figure 7, and Figure 8**.**

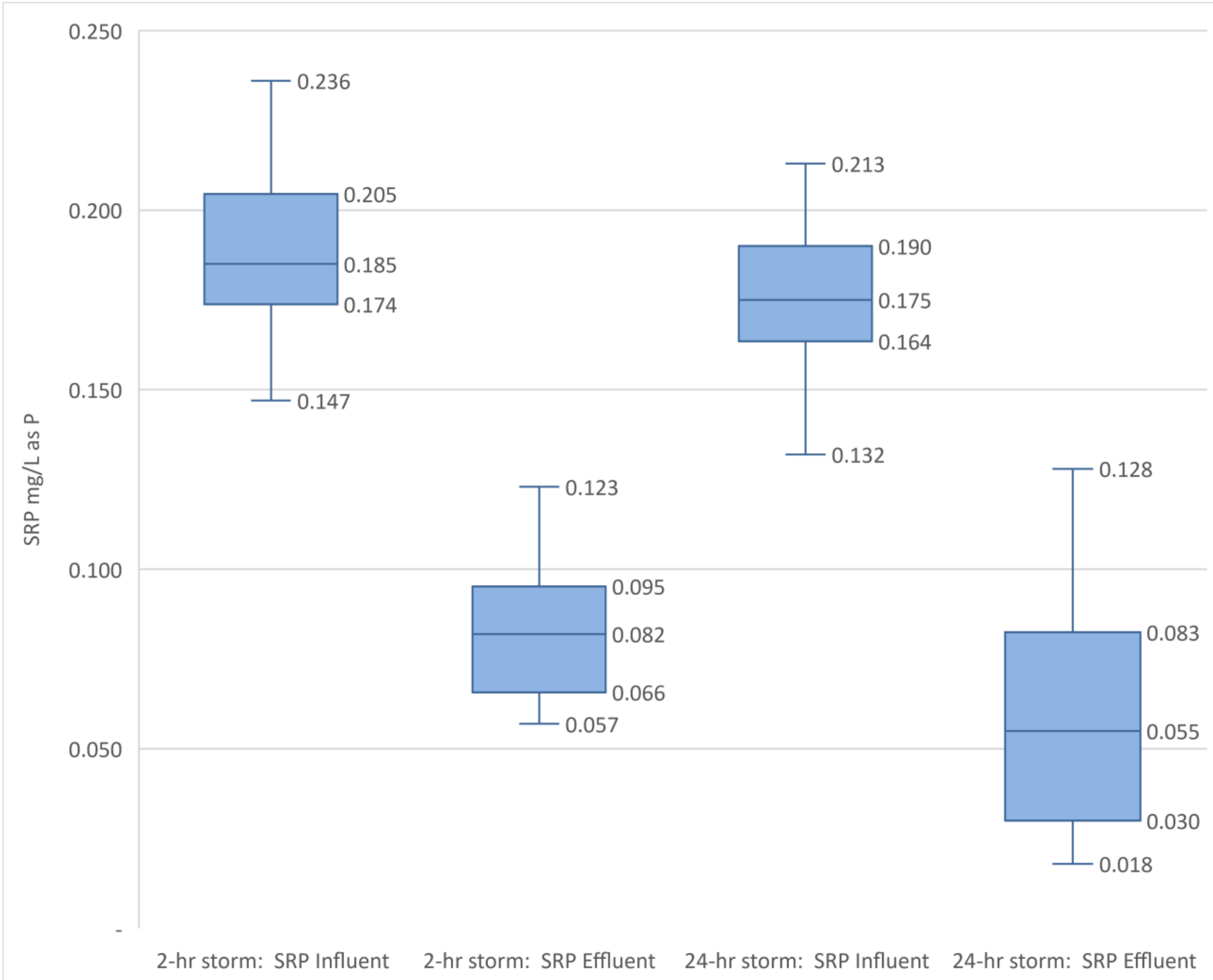


Figure 6: Media 1 SRP

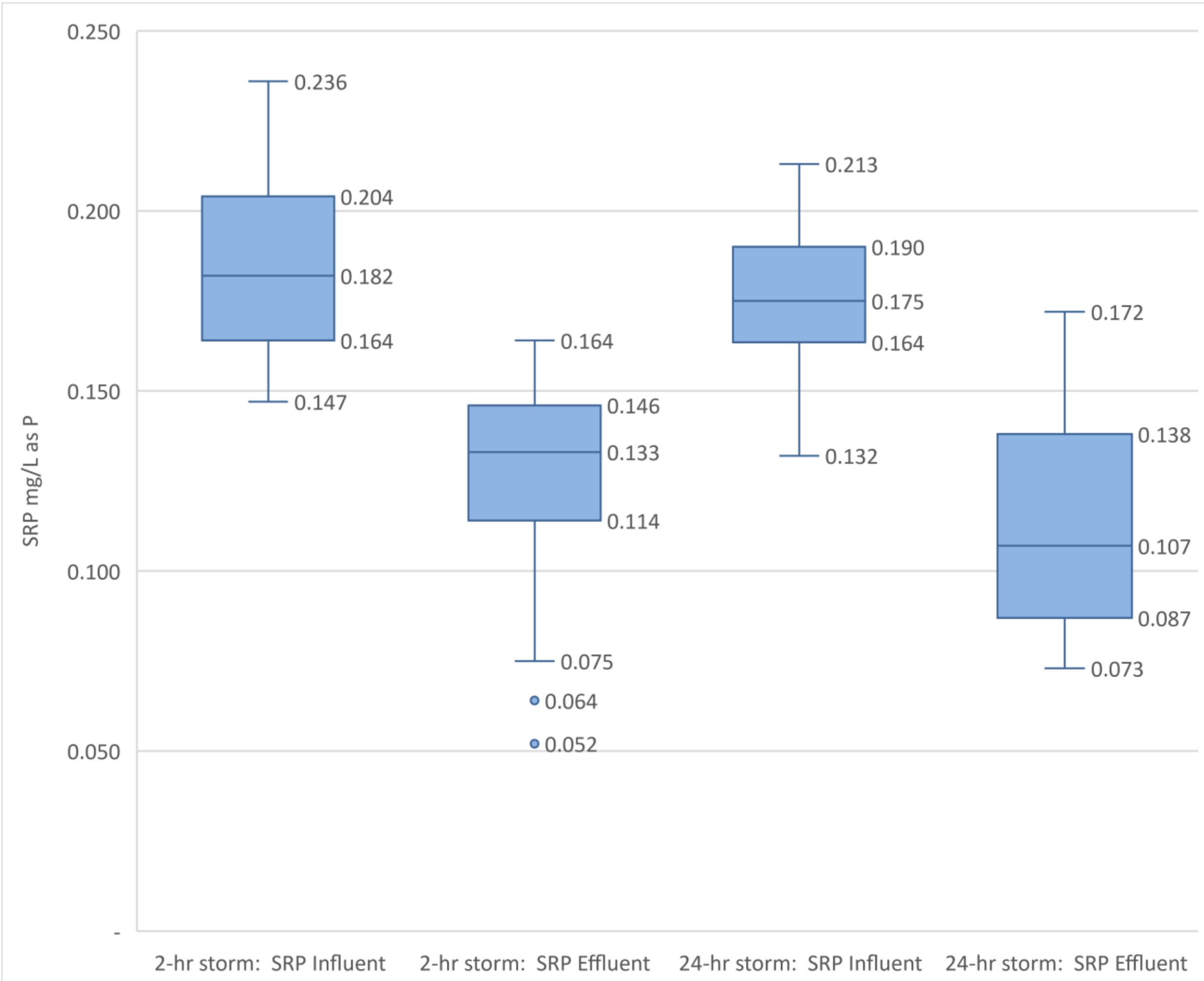


Figure 7: Media 2 SRP

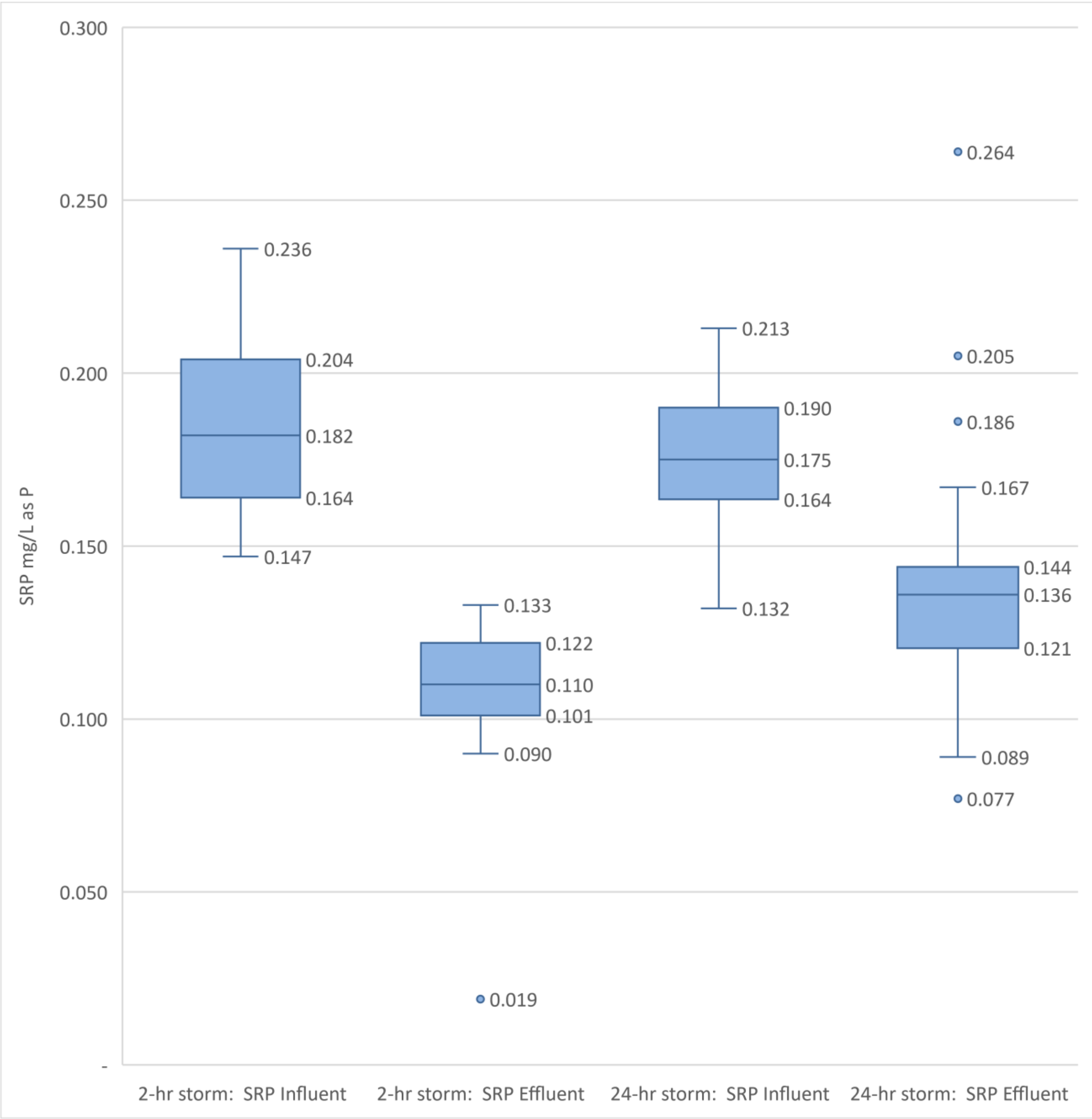


Figure 8: Media 3 SRP

Media 1 performed better than the other media in terms of SRP removal for both the two-hour and 24-hour storm events, see Table 7. In addition, the longer contact time of the 24-hour storm event increased SRP removal efficiency for Media mixes 1 and 2 by 10%; however, Media 3 experienced a decrease in SRP removal with the extended contact time.

Table 7: Soluble Reactive Phosphorus Removal for each Media

Approximate Flow Duration (hours)	**EBCT (minutes)**	**Media #**	**Influent SRP (mg/L as P)**	**Effluent SRP (mg/L as P)**	**Δ SRP (mg/L as P)**	**SRP % Removal**
2	22	1	0.185	0.082	-0.103	56%
		2	0.182	0.133	-0.049	27%
		3	0.182	0.110	-0.072	40%
24	220	1	0.175	0.055	-0.120	69%
		2	0.175	0.107	-0.068	39%
		3	0.175	0.136	-0.039	22%

Note:
Δ = Effluent – Influent, thus a positive Δ indicates an increase and a negative Δ indicates a decrease.

Total Phosphorus

Data from the duplicate A and B columns was combined to produce a more robust data set for total phosphorus performance. Box and whisker plots were utilized to identify the median values of the influents and effluents, as well as the outlier, see Figure 9, Figure 11, and Figure 12.

In Figure 9 there is an extreme outlier of total phosphorus for the effluent of Media 1 during the 24-hour simulated storm event. This outlier only occurred in the B column of the duplicate pair on 9/24/2013, indicating there was an event that happened specifically to that column. There is no corresponding outlier in SRP for that column (see Figure 6), however there was an outlier in Total Suspended Solids (TSS) (5.75 mg/L) for the Media 1 effluent from the column for that date, see Figure 10. This corresponding outlier in both total phosphorus and TSS for the same column on the same date indicates that there may have been a sloughing of biofilm or a breakaway of some small pieces of media that exited out of the column thus causing a sudden spike in TSS and total phosphorus.

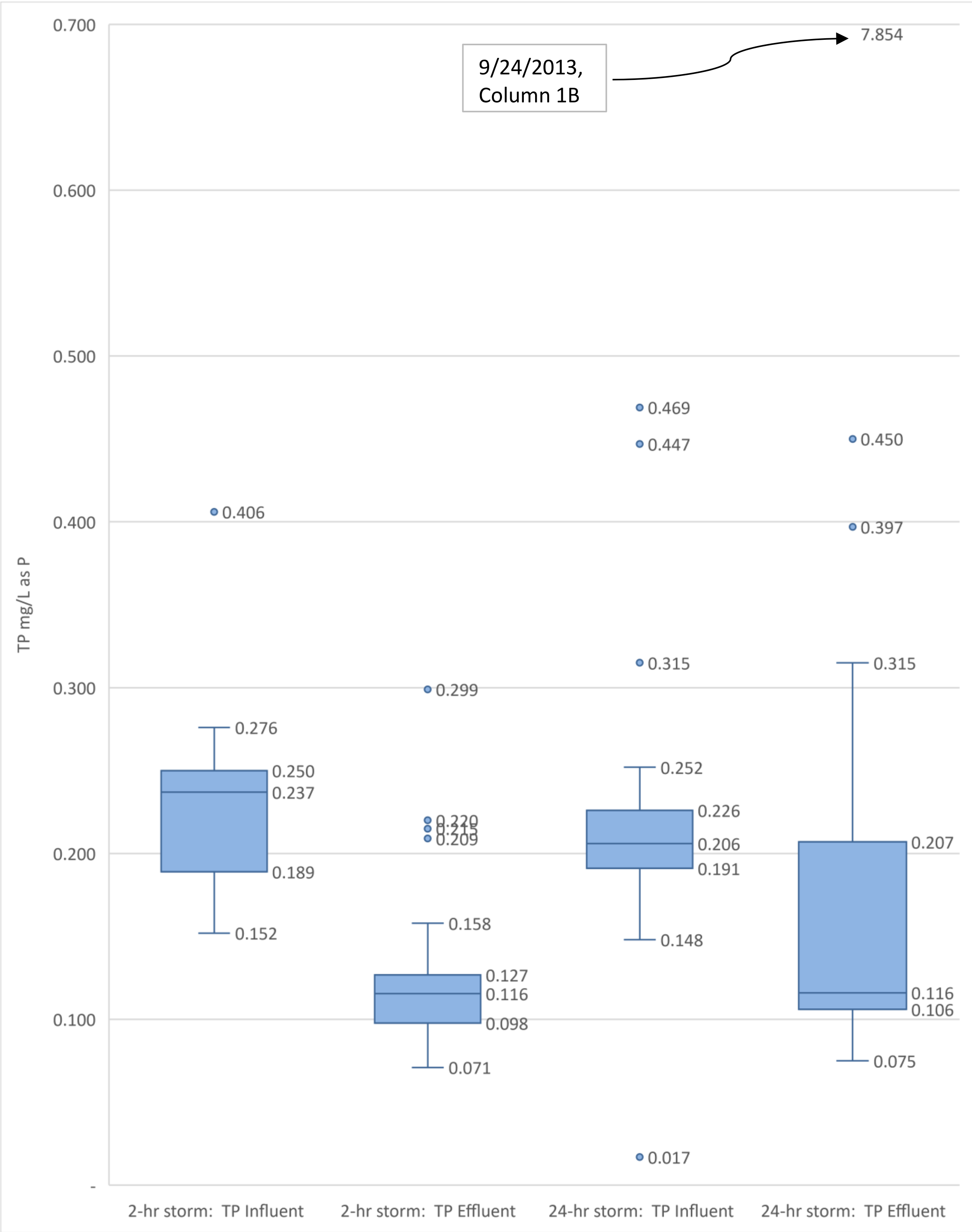


Figure 9: Media 1 Total Phosphorus

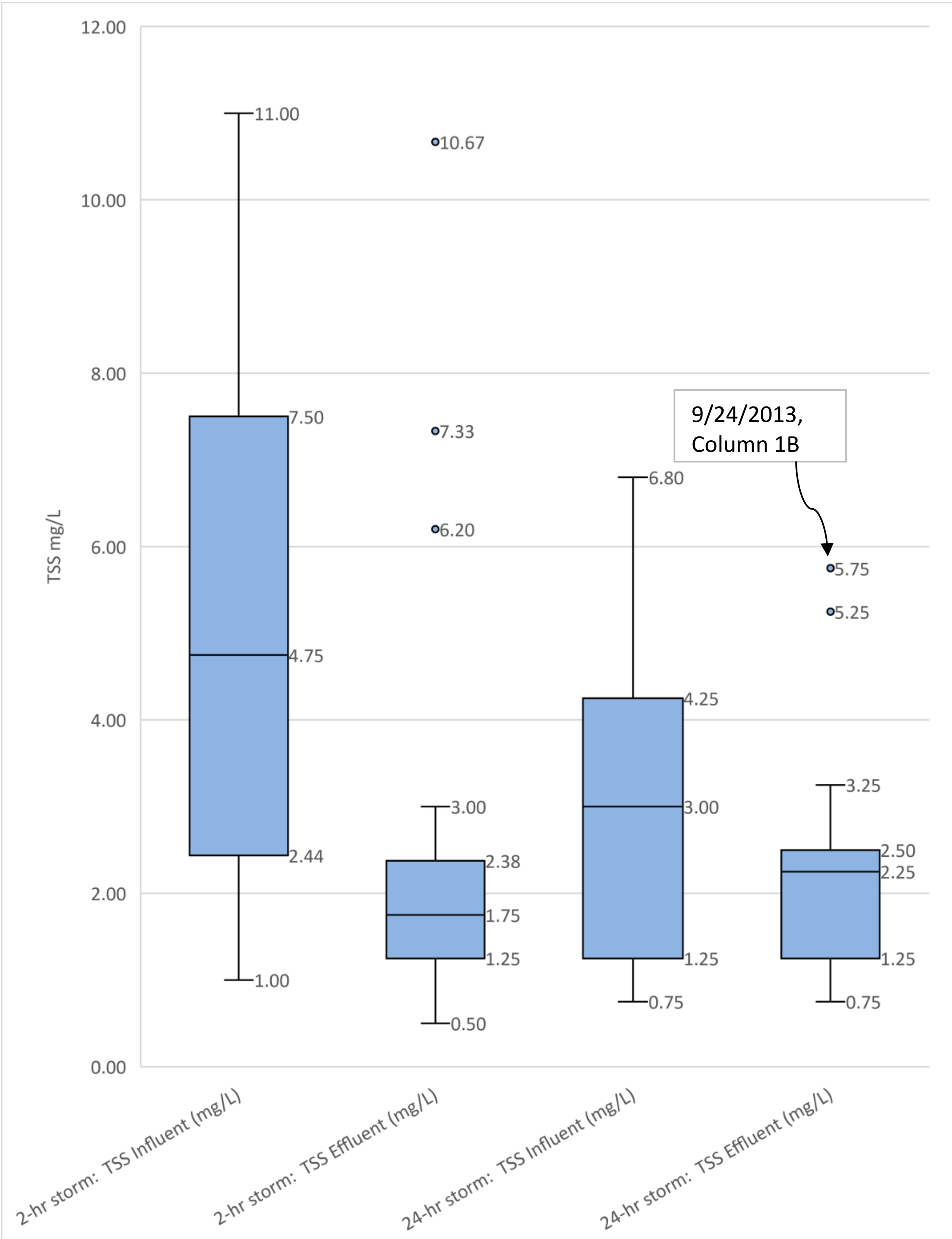


Figure 10: Media 1 TSS

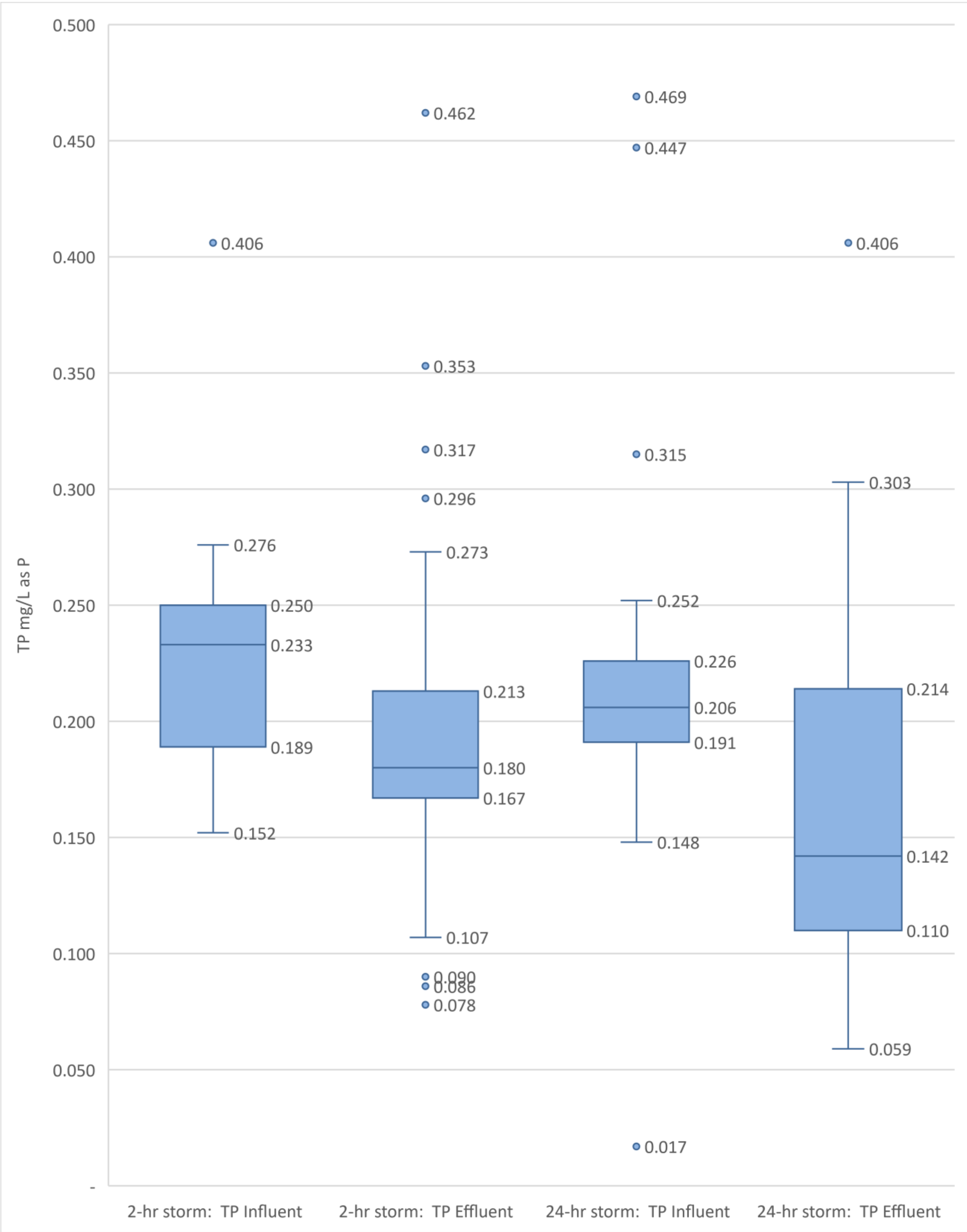


Figure 11: Media 2 Total Phosphorus

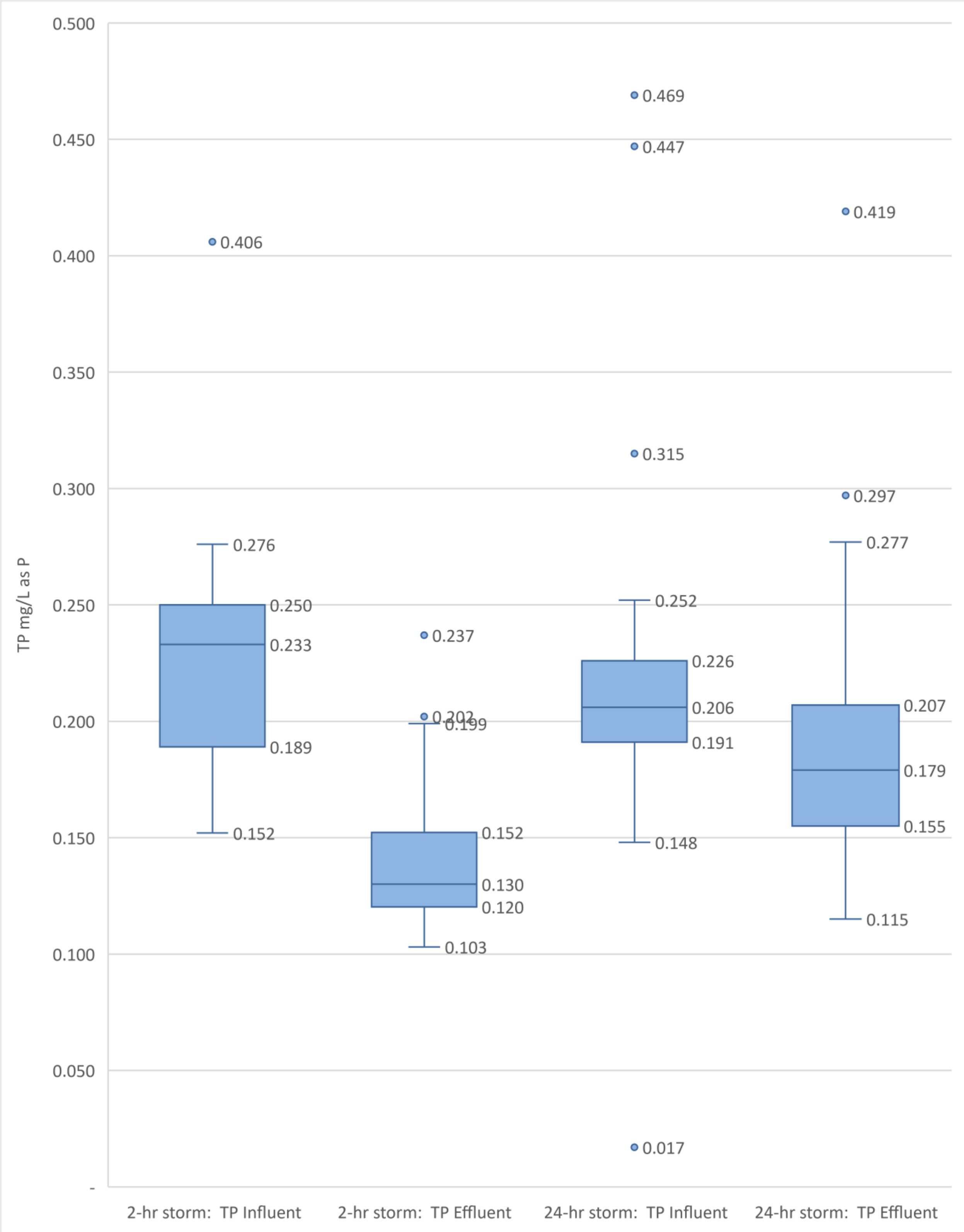


Figure 12: Media 3 Total Phosphorus

Overall, the total phosphorus data is more variable than the SRP data, see Figure 6, Figure 7, Figure 8, Figure 9, Figure 11, and Figure 12. The sloughing of biofilm, suspension and washing out of fine BAM material, or other non-steady state events likely contributed to the variability. Over an extended number of sampling events the system is assumed to operate under steady-state conditions; for example, as biofilm grows and assimilates SRP, biofilm will also slough off and release non-SRP phosphorus. The sloughing of biofilm may not occur during every sampling event, but over an extended time the growth rate and sloughing rate of the biofilm will reach steady state. Table 8 presents the total phosphorus data for each media type. Just as with SRP, Media Mix 1 performed the best for both the 2 and 24-hour storm events for total phosphorus removal, however the total phosphorus removal efficiency was lower than the SRP removal efficiencies for most media types. This is because most of the total phosphorus removal is accounted for by the SRP removal. Media 3 during the 2-hour storm event is the only exception to this trend. This is perhaps due to Media 3 containing limestone screenings which are known to flocculate dissolved phosphorus [78-81]. The likely reason for Media 1's superior performance for both total phosphorus and SRP was likely its combined total of 75% 50/50 expanded clay and 3/8 inch expanded clay and its higher tire crumb content than any other media tested. Tire crumb and clay are excellent at sorption of phosphorus [27, 35, 49, 52, 62-65].

In some cases, the columns are generating non-SRP phosphorus, likely due to biofilm sloughing and exiting the system in the effluent (see Table 9) [47]. Non-SRP phosphorus was defined in Figure 3. Sloughed biofilm in the effluent would explain why, for all BAM types during the 220 minute EBCT and Media 2 during the 22 minute EBCT, that SRP reduction was greater than total phosphorus reduction. Figure 13 illustrates how in addition to sorption to the BAM, SRP was being biologically assimilated into the biofilm and was sloughed off as a non-

SRP component of total phosphorus, thus leading to in some in some cases an increase in non-SRP phosphorus, see Table 9.

Table 8 Total Phosphorus Removal for each Media

Approximate Flow Duration (hours)	EBCT (minutes)	Column Media #	Average Influent TP (mg/L as P)	Average Effluent TP (mg/L as P)	Δ TP (mg/L as P)	TP % Removal
2	22	1	0.237	0.116	-0.122	51%
		2	0.233	0.180	-0.053	23%
		3	0.233	0.130	-0.103	44%
24	220	1	0.206	0.116	-0.090	44%
		2	0.206	0.142	-0.064	31%
		3	0.206	0.179	-0.027	13%

Note:
Δ = Effluent – Influent, thus a positive Δ indicates an increase and a negative Δ indicates a decrease (aka reduction).

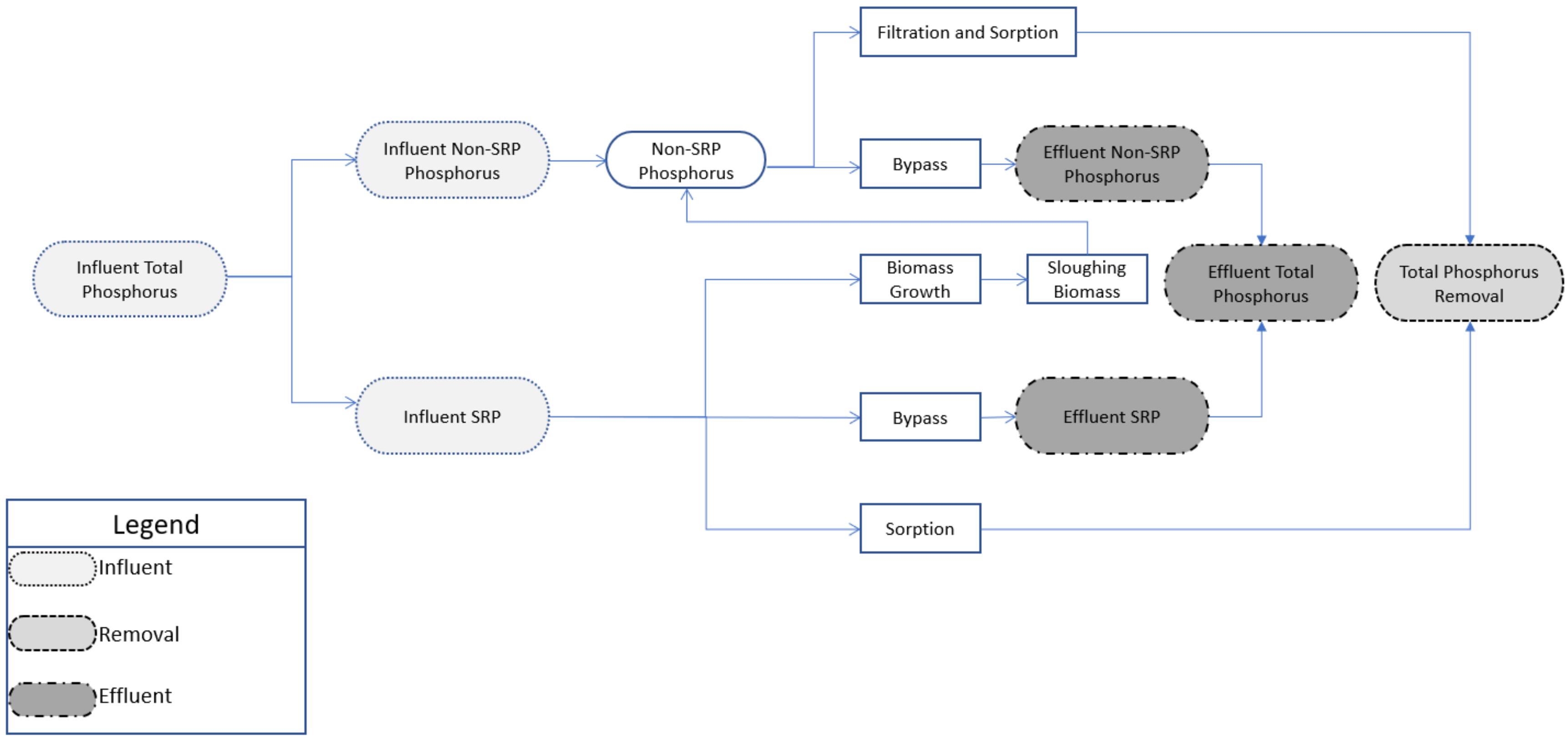


Figure 13: Phosphorus Transformations and Removal

Table 9: Summary of Change in Phosphorus by Type

Approximate Flow Duration (hours)	EBCT (minutes)	Column Media #	Type of Phosphorus	Influent (mg/L as P)	Effluent (mg/L as P)	Δ (mg/L as P)	% Reduction
2	22	1	Total Phosphorus	0.237	0.116	-0.122	51%
			SRP	0.185	0.082	-0.103	56%
			Non-SRP Phosphorus	0.052	0.034	-0.019	36%
		2	Total Phosphorus	0.233	0.180	-0.053	23%
			SRP	0.182	0.133	-0.049	27%
			Non-SRP Phosphorus	0.051	0.047	-0.004	8%
		3	Total Phosphorus	0.233	0.130	-0.103	44%
			SRP	0.182	0.110	-0.072	40%
			Non-SRP Phosphorus	0.051	0.020	-0.031	61%
24	220	1	Total Phosphorus	0.206	0.116	-0.090	44%
			SRP	0.175	0.055	-0.120	69%
			Non-SRP Phosphorus	0.031	0.061	0.030	-97%
		2	Total Phosphorus	0.206	0.142	-0.064	31%
			SRP	0.175	0.107	-0.068	39%
			Non-SRP Phosphorus	0.031	0.035	0.004	-13%
		3	Total Phosphorus	0.206	0.179	-0.027	13%
			SRP	0.175	0.136	-0.039	22%
			Non-SRP Phosphorus	0.031	0.043	0.012	-39%

Note:
•Δ = Effluent – Influent, thus a positive Δ indicates an increase and a negative Δ indicates a decrease (aka reduction).
•A negative % Reduction indicates an increase.

Conclusions

The removal of phosphorus from stormwater is a common goal for stormwater engineers when designing a structural BMP. This study demonstrated that upflow BAM treatment systems are a viable solution for the removal of phosphorus that is in a dominantly dissolved or non-settable solid form.

Media 1 had the best SRP and Total Phosphorus performance during both the 2 and 24 hour storm events, 22 minute and 220 minute EBCTs respectively. Media 1 was not effective at removing the Non-SRP component of Total Phosphorus during the 220-minute EBCT; however, SRP is the species of phosphorus that is readily available for biological assimilation, thus SRP is the phosphorus species of most concern for nutrient capture [72]. As SRP is the readily available form of phosphorus for biological assimilation, SRP was being biologically assimilated into the biofilm and transformed into non-SRP phosphorus. As the biofilm was sloughed off, the non-SRP component of total phosphorus would exit the BAM filtration system. Sloughed biofilm in the effluent would explain why, for all Media types during the 220 minute EBCT that SRP reduction was greater than TP reduction.

Media 1 also had an extremely high permeability constant (see Table 2). This indicates that Media 1 will require much less driving head than the other BAM mixes considered and will be less prone to flow rate performance loss due to clogging.

In addition to containing more tire crumb than any other BAM considered, Media 1 also contains a combined total of 75% 50/50 expanded clay and 3/8 inch expanded clay. Clay is an excellent adsorption media for phosphorus and expanded clay is extremely porous and thus provides substantial surface area for adsorption of phosphorus [27, 35, 49, 52, 62-65].

Automobile tires are generally composed of 27% to 33% carbon black by mass; carbon black functions similarly to activated carbon and has been shown to work well for phosphorus sorption [35, 51, 52]. Thus, the large proportions of expanded clay and tire crumb are likely the reason for the superior phosphorus removal performance of Media 1.

CHAPTER 4: THE EFFECTS ON BACTERIAL WATER QUALITY INDICATORS OF UPFLOW BAM TREATMENT ON STORMWATER

Abstract

Stormwater runoff is a main source of pollution in surface water bodies near urban areas and often contains elevated levels of pathogens which can pollute the receiving water body, causing adverse health impacts on humans and wildlife that interact with the water body [1, 2]. Sand filters have been proven effective at removing microbial indicators from stormwater, however sand filters are not overly effective at removing nutrient pollutants [48]. Biosorption Activated Media (BAM) however has proven effective in removal of nutrient pollutants through the sorption of phosphorus and biological removal of nitrogen but there is not a great deal of literature regarding its usage as a stormwater BMP (Best Management Practice) for pathogen removal [25, 27, 48]. Since structural BMPs are often designed to target multiple pollutants it is desirable to know the performance of BAM for pathogen treatment. This research simulated stormwater that had already been treated or solids removal; thus, the nutrients and solids in the influent were assumed to be mostly non-settable suspended solids or dissolved. This paper compares three different BAM mixtures in a bench scale, upflow filter configuration for the parameters of total coliform, E. coli, and heterotrophic plate counts. The columns were run at both 22-minute and 220-minute Empty Bed Contact Time (EBCT). The BAM compositions in this study were composed of various ratios of limestone screenings, AASHTO (American Association of State Highway and Transportation Officials) classification A-3 sand with 1.8% silt/clay, AASHTO A-3 sand with 7.1% silt/clay, 50/50 ratio course and fine expanded clay, 3/8

inch expanded clay, and tire crumb. During the 22 minute EBCT, BAM 1, which had the greatest total sorption material content and no sand content, had the best total coliform removal performance, while BAM 3 which had the greatest sand content (physical filtration) had the lowest. Thus, it can be concluded that in BAM upflow filters, total coliform was dominantly removed by sorption rather than physical filtration.

Keywords: biosorption activated media; BAM; stormwater; bio-filtration; tire crumb; expanded clay; total coliform; E. coli; heterotrophic plate count; HPC; water quality; sustainability; highway runoff; best management practice; BMP

Introduction

Stormwater runoff is a main source of pollution in surface water bodies near urban areas and can contain elevated levels of pathogens which can pollute the receiving water body, causing adverse health impacts on humans and wildlife that interact with the water body [1, 2]. The microbial pollution of surface water bodies can cause closures of water bodies for recreational and commercial use and issues with downstream uses such as drinking water [1, 2, 61, 88]. Common sources of pathogens in urban stormwater include lawns, roads, animal waste, septic systems, and leaky sanitary sewer lines [88].

Stormwater Best Management Practices (BMPs), in regard to microbial water quality, are commonly assessed using the indicators of total coliform and E. coli bacterial levels and total heterotrophic plate counts (HPCs). All these parameters are also United States Environmental Protection Agency (US EPA) primary drinking water standards which is relevant since there has been increased interest in utilizing stormwater harvesting as a drinking water source [61, 89-96]. Total coliforms are not necessarily a health threat but are used as an indicator for the presence of other potential harmful bacteria [61, 94]. Additionally, total coliform levels are regulated in some states for reuse applications such as irrigation [3]. E. coli is a type of coliform bacteria that indicates fecal contamination of the water, the presence of E. coli is a strong indicator of the presences of pathogens [94]. E. coli levels are regulated in the effluent discharging into recreational water bodies and for reuse applications making them an important stormwater BMP performance criteria [3, 89]. HPCs estimate the population of heterotrophic bacteria in the water and are used to evaluate the performance of bacterial treatment systems and to estimate how much bacterial growth may occur in the distribution system if the water is harvested for reuse applications [61]. Although stormwater effluent HPC levels are not regulated there are implications for reuse purposes. As aquifers have become depleted, there has been interest in harvesting stormwater as a source for drinking water plants. Heterotrophic bacteria are known to cause biofouling in membrane based drinking water treatment such as reverse osmosis [3, 4]. HPC levels are also regulated by the US EPA as a primary drinking water standard when source water is surface water or groundwater under the direct influence of surface water [94].

Bacteria and viruses in stormwater are often bound to particulate matter (8% - 55%), as a result stormwater structural BMPs at the site level which focus on particulate removal have proven effective in removing fecal indicator bacteria from stormwater [97]. These structural BMPs include wet detention, filter basins, baffle boxes, and in-line filters [93, 98, 99]. Filter basins and wet detention, however, require a large footprint and may not be feasible for ultra-urban areas or stormwater system retrofits. In-line and off-line media filters, hence forth simply referred to as filters, however, can require a much smaller footprint since they can be installed underground. An ideal implementation of an upflow BAM filter system would be after the stormwater has already been treated by a solids removal system such as a baffle box, vortex separator, or stormwater pond. The removal of solids prior to entering the BAM upflow filter will prevent clogging thus extending the service life. This research simulated stormwater that had already been treated for solids removal; thus, most of the nutrients and other solids in the simulated stormwater influent were likely as non-settable suspended solids or dissolved solids.

Sand filters have been proven effective at removing microbial indicators from stormwater, however sand filters are not overly effective at removing pollutants such as ortho-phosphorus from stormwater [48]. Biosorption Activated Media (BAM) however has proven effective in removal of nutrient pollutants through the sorption of phosphorus and biological removal of nitrogen but there is not a great deal of literature regarding its usage as a stormwater BMP for pathogen removal [25, 27, 48]. There have been studies utilizing BAM in septic tank drain fields that have shown effectiveness for removing coliform bacteria [100]. Additionally, there have been studies showing that activated carbon is capable of removing waterborne pathogens via sorption [101-103]. The BAM in this study contained tire crumb, which has been proven in other studies to sorb pollutants in stormwater [51]. Automotive tires are generally composed of 27% to 33% carbon black by mass, carbon black functions similarly to activated carbon [51]. Additionally, the BAM in this research contained expanded clay, which has sorption properties in regards to nutrient removal [35, 104]. The same sorption properties of expanded clay that are utilized in nutrient removal may also aid in pathogen removal, however little literature was located which specifically referenced the use of expanded clay for pathogen removal [35, 104].

Expanded clays are typically composed of an inert ceramic particle with a porous coating. Expanded clay is created by a process known as calcination which involves exposing the clay to temperatures of up to 1200°C inside a rotary kiln [62, 83]. During calcination the organic matter in the clay expands resulting in a high porosity, low bulk density aggregate. Furthermore, the expanded clay has a higher hydraulic conductivity (aka permeability) than similarly sized gravels and sands [62].

An extensive discussion of sorption and physical filtration processes with respect to BAM can be found in Hood [35]. Although the literature indicates that activated carbon is suited for coliform removal, studies have shown that HPC levels increase in activated carbon filters due to the bacterial colonization of the granular activated carbon [105]. BAM relies on the bacterial colonization of the media to achieve nitrogen removal, including chemoheterotrophic denitrifying bacteria [51, 61, 106]. Thus, like the activated carbon filters from literature, BAM may also result in an increase in HPC [105].

BAM can consist of one or more types of media, including tire crumb or chips, expanded clay, and limestone screenings, which are blended to achieve specified pollutant removal effectiveness; there is a wide selection of media mixtures that have been tested and are used in media filtration systems [25]. BAM, when consisting of larger diameter components such as expanded clay, can have very high permeability and thus is a good option for high flow rates when nutrient removal is needed. However, there is not a large amount of data pertinent to its microbe removal abilities. Furthermore, BAM removes nitrogen through biological processes and is designed to promote the growth of bacteria for nitrification and denitrification; thus, it is unknown how BAM will perform as a bacterial pathogen removal method for stormwater [51].

Downflow filters are simple and commonly utilized in stormwater treatment but have long term operational draw backs. They are prone to compaction and clogging of the media, leading to reduced flow rates and shorter life spans [74, 75]. Upflow filters are less prone to clogging; between storm events particulate matter that has caked on the bottom of the upflow filter will fall away; unclogging the filter and maintaining permeability for a longer life span [75]. Upflow filters may be a good option when the goal is to provide sorption surface area for nutrient removal, however the fluidized media, which expands pore spaces, may not provide adequate physical filtration for microbe removal.

Since nutrient and pathogen removal from stormwater are both important design objectives in stormwater structural BMPs that discharge to surface water bodies, the objective of this research was to develop a bench scale upflow filtration system that utilizes BAM, a known method of nutrient removal, and evaluate the microbial pathogen removal performance. Three different BAM mixtures were evaluated during both 2-hour and 24-hour storm events, 22 minute and 220 minute EBCTs respectively, for total coliform, E. coli, and HPC.

Methods

Experimental Design

The BAM in this research was composed of tire crumb, 3/8 inch expanded clay, 50/50 volumetric ratio blend of course and fine expanded clay (hence forth referred to as 50/50 expanded clay), limestone screenings, AASHTO (American Association of State Highway and Transportation Officials) classification A-3 sand with 1.8% silt/clay and AASHTO classification A-3 sand with 7.1% silt/clay. Table 10 presents the compositions of the BAM utilized in the experimentation. The permeability constant, dry density, and dry mass of each BAM type analyzed are presented in Table 11. A brief description of the AASHTO soil classification system as well as particle size distribution curves for the BAM mixes and the individual components can be found in APPENDIX I.

Tire crumb, expanded clay, and limestone screenings have been shown to be effective at removing pollutants from stormwater by a combination of physical filtration of particulates, sorption, and flocculation [27, 35, 52, 60, 62-65, 78-81]. Sand removes pollutants dominantly via biofilms and inert filtration of particulates.

Table 10: BAM Compositions

BAM #	50/50 Expanded Clay	3/8 inch Expanded Clay	Tire Crumb	A-3 sand with 1.8% silt/clay	A-3 sand with 7.1% silt/clay	Limestone Screenings
1	55%	20%	25%	0%	0%	0%
2	0%	25%	0%	50%	25%	0%
3	15%	0%	15%	50%	0%	20%

Note: Percentages were as loose, uncompacted volumetric ratios.

Table 11: BAM Characteristics

BAM #	Permeability constant (in/hr)	Dry Density of BAM in Column (kg/m^3)	Dry Mass of BAM in Column (kg)
1	475.25	579.6	2.9
2	6.733	1242.5	6.1
3	12.86	1246.4	6.2

The bench-scale experiment consisted of three sets of columns, each set with a different media type (1, 2, and 3), see Table 11. Each set of columns consisted of three columns (A, B, and C), for a total of nine columns, see Table 12. All the columns had an internal diameter of 4 inches and the media occupied two feet of each column (Figure 14). See APPENDIX N for a more detailed description of the system design.

The A and B columns were duplicate columns with a single type of BAM until the last 3 weeks of the experiment. The antibiotic vancomycin was added to the B Columns for the last 3 weeks, starting on 11/19/2013, for research related to another study. Thus, bacterial data from the B Columns from that point on was not considered as part of the analysis. The C columns received a nitrification inhibitor, 2-Imidazolidinethione, at a concentration of 10 mg/L in the influent. The nitrification inhibitor was for research related to another study. The nitrification inhibitor may have an effect of the biofilm growth and sloughing, thus data from the C Columns was not used in total suspended solids (TSS), turbidity, or HPC analysis. Total coliform and E. coli analysis was done on the C columns because the presence of nitrification inhibitor should have no effect on the population and removal of total coliform and E. coli bacteria.

Table 12: Column Types

Column Type	**Description**
A	BAM #
B	BAM # (duplicate of A prior)
C	BAM # + Nitrification Inhibitor in influent

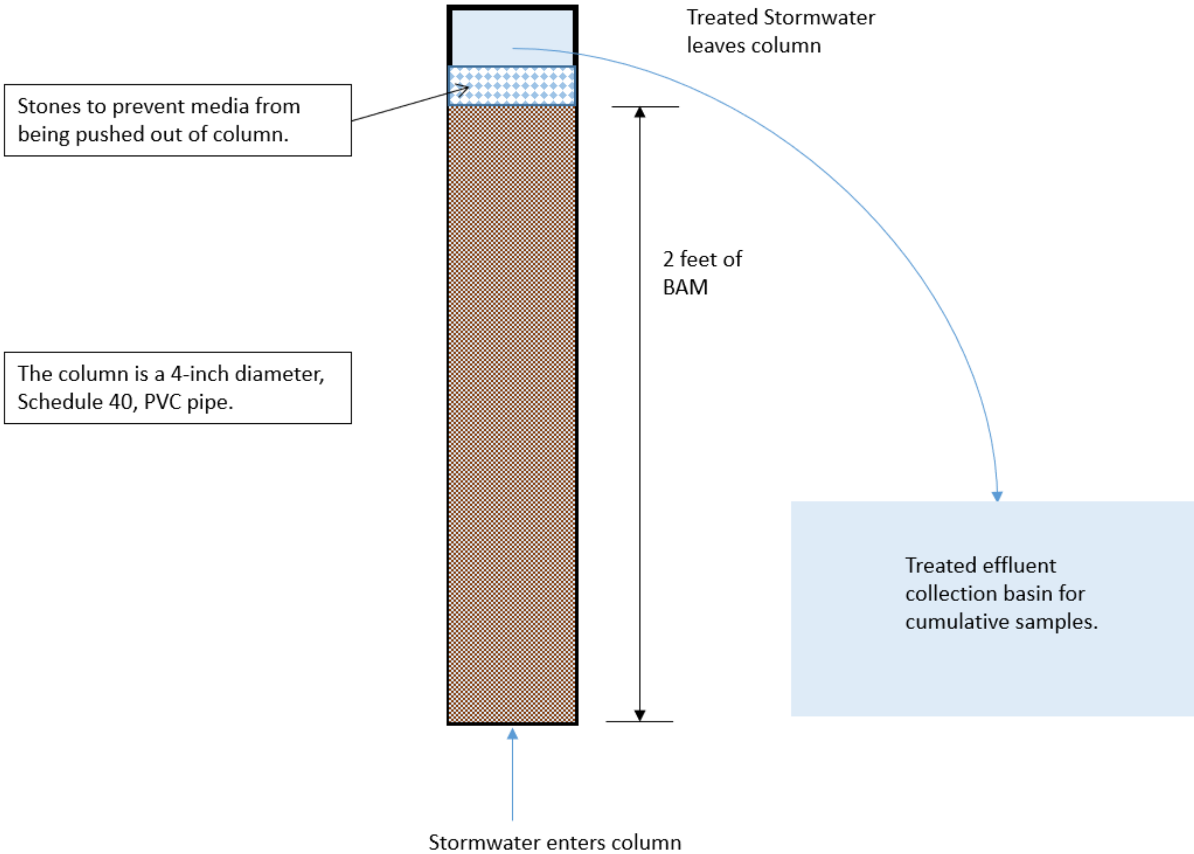


Figure 14: Upflow Column Design

Operation of columns

The simulated stormwater runoff was obtained by spiking water from a stormwater pond with ammonium carbonate, potassium nitrate, and potassium phosphate in order to approximately reach the average highway runoff concentrations for nitrogen and phosphorus species listed in the National Stormwater Quality Database (NSQD), see Table 13 [18]. Actual influent values for each parameter varied due to seasonal variations and other environmental factors affecting the pond. The column operations simulated 2 and 24-hour storm events over an 8 month period.

Table 13: Average Concentrations of Pollutants in Freeway Runoff from the NSQD [18]

Pollutant	National Freeway Runoff Concentrations
NH_3	1.07 mg/L as N
TKN	2.0 mg/L as N
$NO_2^- + NO_3^-$	0.28 mg/L as N
Total Nitrogen	2.28 mg/L as N
Filtered Phosphorus	0.20 mg/L as P
Total Phosphorus	0.25 mg/L as P
pH	7.10
Total Suspended Solids (TSS)	99.0 mg/L

Since the simulated stormwater was obtained from a pond, most of the settable solids had already been removed; the NSQD average TSS for freeway runoff is 99 mg/L whereas the average influent TSS to the BAM columns was 4.75 mg/L and 3.00 mg/L for the 22-minute and 220-minute EBCTs respectively. Additionally, since dissolved forms of nitrogen and phosphorus were used to spike the pond water for nutrient content, it can be assumed that most of the nutrients are either as dissolved or non-settable suspended solids. Thus, the simulated stormwater represents stormwater that had been already treated for solids removal by a baffle box or pond and the remaining nutrient content is mostly as dissolved or non-settable suspended solids.

There were three 2-hour, high intensity, storm events per week and one 24-hour, lower intensity, storm event per week with EBCTs of 22 minutes and 220 minutes respectively. Sampling events occurred periodically during the last 5 months of operation for both 2 and 24-hour storm events.

Based on the dimension for each (a diameter of 4 inches and a height of 24 inches), the total volume was 302 in^3 and each has a cross-sectional area of 12.57 in^2. The empty bed contact time (EBCT) and hydraulic loading rates were calculated from the actual volume of effluent collected from each column. There was little column-to-column variation for the EBCT and hydraulic loading rates for both the 2 and 24-hour rates. The average EBCT and hydraulic loading rates are presented in Table 14.

Table 14: EBCT and Hydraulic Loading Rate

Flow Duration (hours)	Empty bed Contact time (minutes)	Hydraulic Load per unit volume of media "1/hour" (in^3 water / hour) / (in^3 of media)	Hydraulic Load per cross -sectional area (aka the flux) (gallons water / minute) / (ft^2 of cross section)
2	22	2.723	0.679
24	220	0.273	0.068

Water sampling

A grab sample was taken from the barrel supplying the influent barrel. Each column's entire effluent was collected in a container to create a cumulative sample and a grab sample was collected at the completion of the simulated storm event from the container. The influent and effluent samples were tested for total coliform and E. coli using IDEXX Quanti-Tray/2000. HPC and Total Suspended Solids (TSS) were performed according to Standard Methods [107, 108].

Results & Discussions

Determining the permeability constant for the BAM types is an important design parameter. The permeability constant will determine how much head is needed to achieve desired flow rates and EBCT when designing field scale implementation BMPs. The permeability constant for each BAM type is presented in Table 2. BAM 1 had the highest permeability constant by far and thus would require the least driving head to achieve a desired flow rate. The tire crumb and expanded clay are larger particles than AASHTO A-3 sand with 1.8% silt/clay and thus have larger pore sizes, therefore the permeability constant of BAM 1 is much greater than BAM 2 and BAM 3.

The influents and effluents of the various BAM varieties were analyzed for E. coli with the goal of determining the reduction efficiency since E. coli concentrations are regulated in the discharge to recreational water bodies criteria [89]. Unfortunately, the source water used for the influent was determined to have E. coli concentrations right at or below the detection limit of 100 Most Probable Number (MPN) per 100 mL. The only date that had E. coli present in the influent at quantities above detection limit was 8/7/2018 and all BAM varieties had the same result of reducing the E. coli to below detection limit; the data for 8/7/2013 is highlighted in

Table 15, Table 16, and Table 17. Based on the two data points for each BAM variety it can be tentatively concluded that upflow BAM filters are capable of reducing E. coli concentrations, but it is not possible to determine a quantifiable comparison between the BAM varieties.

Table 15: BAM 1 E. Coli Removal

Approximate Flow Duration (hours)	EBCT (minutes)	Date	Column	Influent E. Coli (MPN per 100 mL)	Effluent E. Coli (MPN per 100 mL)
2	22	7/31/2013	A	<100	100
		8/7/2013	A	202	<100
		8/7/2013	B	202	<100
		8/7/2013	C	100	<100
		11/22/2013	A	<100	<100
		11/22/2013	C	<100	100
		12/11/2013	A	<100	<100
		12/11/2013	C	<100	<100
24	220	11/19/2013	A	<100	<100
		11/19/2013	C	<100	<100
		12/12/2013	A	<100	<100
		12/12/2013	C	<100	<100

Table 16: BAM 2 E. Coli Removal

Approximate Flow Duration (hours)	EBCT (minutes)	Date	Column	Influent E. Coli (MPN/100 mL)	Effluent E. Coli (MPN/100 mL)
2	22	7/31/2013	C	<100	<100
		8/7/2013	A	202	100
		8/7/2013	C	100	<100
		11/22/2013	A	<100	100
		11/22/2013	C	<100	<100
		12/11/2013	A	<100	<100
		12/11/2013	C	<100	<100
24	220	11/19/2013	A	<100	<100
		11/19/2013	C	<100	100
		12/12/2013	A	<100	<100
		12/12/2013	C	<100	<100

Table 17: BAM 3 E. Coli Removal

Approximate Flow Duration (hours)	EBCT (minutes)	Date	Column	Influent E. Coli (MPN per 100 mL)	Effluent E. Coli (MPN per 100 mL)
2	22	8/7/2013	A	202	<100
		8/7/2013	C	100	<100
		11/22/2013	A	<100	<100
		11/22/2013	C	<100	<100
		12/11/2013	A	<100	<100
		12/11/2013	C	<100	<100
24	220	11/19/2013	A	<100	<100
		11/19/2013	C	<100	<100
		12/12/2013	A	<100	<100
		12/12/2013	C	<100	<100

Unlike E. coli, total coliform was present in the simulated stormwater and all three BAM varieties were shown to be capable of removing total coliform in both the 2 and 24-hour storm events. During the 2-hour storm event, which had an empty bed contact time of 22 minutes, BAM 1 and 3 preformed best with total coliform removal efficiencies of 76% and 65% respectively (Table 18). BAM 1 & 3 were also the two media types that had tire crumb as a component, which behaves like activated carbon and should remove total coliform bacteria based on the literature [94-96]. These two BAM types also had the highest TSS removal efficiencies during the 2-hour storm event, with BAM 1 and 3 having TSS removal efficiencies of 63% and 74% respectively, see Table 19. The lower TSS removal for BAM 2, despite being composed of 50% AASHTO A-3 sand with 1.8% silt/clay, may be due to some wash out of silt/clay from the AASHTO A-3 sand with 7.1% silt/clay which was observed by the researcher during the higher flow rate of the 2-hour storm events; this was reflected in the increase in turbidity for BAM 2, see Table 20. It is worth noting that the BAM 1 had the highest total coliform removal but did not have the highest TSS removal. BAM 3 achieved a higher TSS removal than BAM 1 and unlike BAM 1, it contained sand. This indicates that TSS and total coliform removal may not be related and that a mechanism besides inert filtration, such as sorption, is the primary mechanism for total coliform removal. Another possible reason that the BAM type ranking of TSS removal and total coliform are not in the same order, as one would expect if total coliform bacteria are associated with solids, is sloughed biofilm may be exiting they system in the effluent. BAM upflow filters are biologically active and a steady state will be reached in which over time biofilm growth will equal biofilm sloughing [47]. Sloughed biofilm may have been a component of effluent TSS [38, 47, 61]. The generation of suspended solids due to sloughing biofilm in the columns may have obscured a relationship between total coliform removal and the removal of influent supplied TSS.

Table 18: Total Coliform Removal

Approximate Flow Duration (hours)	EBCT (minutes)	Media #	Median Influent Total Coliform (MPN per 100 mL)	Median Effluent Total Coliform (MPN per 100 mL)	Δ Total Coliform (MPN per 100 mL)	% Removal of Total Coliform
2	22	1	6876	1664	-5213	76%
		2	7057	3684	-3373	48%
		3	6876	2418	-4458	65%
24	220	1	3424	151	-3273	96%
		2	3424	254	-3170	93%
		3	3424	203	-3221	94%

Note:
Δ = Effluent – Influent, thus a positive Δ indicates an increase and a negative Δ indicates a decrease.

Table 19: TSS Removal

Approximate Flow Duration (hours)	EBCT (minutes)	Column Media #	Median Influent TSS (mg/L)	Median Effluent TSS (mg/L)	Δ TSS (mg/L)	TSS % Removal
2	22	1	4.75	1.75	-3.00	63%
		2	4.75	2.50	-2.25	47%
		3	4.75	1.25	-3.50	74%
24	220	1	3.00	2.25	-0.75	25%
		2	3.00	1.75	-1.25	42%
		3	3.00	1.75	-1.25	42%

Note:
Δ = Effluent – Influent, thus a positive Δ indicates an increase and a negative Δ indicates a decrease.

Table 20: Turbidity

Approximate Flow Duration (hours)	EBCT (minutes)	Column Media #	Median Influent Turbidity (NTU)	Median Effluent Turbidity (NTU)	Δ Turbidity (NTU)	Turbidity % Removal
2	22	1	3.250	1.820	-1.430	44%
		2	3.250	6.125	2.875	-88%
		3	3.250	2.255	-0.995	31%
24	220	1	1.820	1.840	0.020	-1%
		2	1.995	1.400	-0.595	30%
		3	1.820	1.505	-0.315	17%

Note:
Δ = Effluent – Influent, thus a positive Δ indicates an increase and a negative Δ indicates a decrease.

During the 24-hour storm event, BAM 1 again preformed the best for total coliform removal with an efficiency of 96%, however it performed the worst for TSS removal with an efficiency of 25%; it is also possible that BAM 1 is releasing TSS into the effluent from the upper column layer. BAM 2 & 3 had almost identical total coliform and TSS removal efficiencies during the 24-hour storm event. Both BAM 2 & 3 were composed of 50% AASHTO A-3 sand with 1.8% silt/clay, whereas BAM 1 contained none. The superior, and identical TSS removal, by BAM 2 & 3 indicates that TSS is dominantly removed via inert filtration rather than adsorption. This inverse relationship of TSS and total coliform efficiency during both the 2 and 24-hour storm events indicates that TSS and total coliform removal are not linked.

During the 2-hour simulated storm events, BAM 1, which contained the most sorption material (clay and tire crumb), had superior total coliform removal performance. BAM 3 which had the second most sorption material content achieved the second highest total coliform reduction during the 2-hour simulated storm event. During the 2-hour simulated storm event, BAM 3 achieved the lowest total coliform removal and had the highest sand content (physical filtration) and lowest sorption material content. Thus, it can be concluded that total coliform is being dominantly removed in the upflow filters by sorption rather than physical filtration.

For all three BAM types, the total coliform removal efficiency increased with the increase in EBCT from the 2-hour to the 24-hour. During the 24-hour storm event, the difference between total coliform removal efficiencies of the BAM types was not nearly as significant as during the 2-hour event; during the 24-hour event, BAM 2 had the lowest total coliform removal performance of 93% and BAM 1 had the highest at 96%. This close removal performance indicates that with the increase in EBCT, the BAM types with less overall sorption material were still able to efficiently sorb total coliform.

During both the 2 & 24-hour storm events there was an increase in HPC for all BAM types except BAM #3 during the 2-hour storm event, see Table 21. Limestone has been used to precipitate total solids in biological waste [81]. Since BAM #3 was the only BAM type to contain limestone screenings, perhaps this contributed to the HPC reduction during the 2-hour storm event. With the exception of BAM #3 during the 2-hour storm event, an increase in HPC is concurrent with what the literature reported for granular activated carbon filters in wastewater plants [105]. The 24-hour simulated storm event experienced a greater increase in HPC than the 2-hour event; this is likely due to the greater EBCT, which allowed for more microbial growth. BAM is designed to foster the growth of bacterial populations in order achieve nitrogen removal via biological bacterial processes, such as denitrification via anoxic heterotrophic bacteria. Additionally, other heterotrophic bacteria, both aerobic and anaerobic, would also grow as a biofilm in the BAM. Thus, it makes sense that stormwater passing through a BAM filter would experience an increase in HPC. An increase in HPC indicates that sloughed biofilm was in the effluent. The increase of HPC, strengthens the conclusion that the generation of suspended solids due to sloughing biofilm in the columns may obscure a relationship between total coliform removal and the removal of influent supplied TSS.

Table 21: HPC

Approximate Flow Duration (hours)	EBCT (minutes)	Media #	Median Influent HPC (CFU/mL)	Median Effluent HPC (CFU/mL)	Δ HPC (CFU/mL)	HPC % Increase
2	22	1	386250	428000	41750	11%
		2	386250	448750	62500	16%
		3	397500	335000	-62500	-16%
24	220	1	234000	537500	303500	130%
		2	234000	508750	274750	117%
		3	234000	513750	279750	120%

Note:
Δ = Effluent – Influent; thus, a positive Δ indicates an increase and a negative Δ indicates a decrease.

Conclusions

Biosorption activated media is commonly used to treat stormwater for nutrient loadings; this research shows upflow BAM BMPs to also be effective in removing total coliform from stormwater that has a low influent TSS. BAM 1, which had the greatest total expanded clay and tire crumb content, had the best performance for both the 22 minute and 220 minute EBCT, achieving a 76% and 96% removal efficiency respectively, see Table 18. The superior total coliform removal performance of BAM 1, compared to the other two varieties tested, was extremely obvious during the shorter EBCT of the 2-hour simulated storm event. BAM #1 contained the most sorption material, thus the data indicated that in BAM upflow filters, total coliform was dominantly removed by sorption rather than physical filtration. Furthermore, BAM 1 had a very high permeability constant of 475 inches/hour, making it a good choice for total coliform removal with a minimal driving head and minimal head loss. Due to a lack of E. coli presence in the simulated stormwater influent only a tentative conclusion of upflow BAM systems being capable of removing E. coli is possible based on two data points for each BAM type, no quantifiable reduction performance value was determined for the BAM variations.

TSS removal performance did not correspond to total coliform removal performance, which was unexpected since bacteria are normally associated with particulate matter [97]. Higher TSS removals corresponded to BAM types with higher volumetric ratios of smaller diameter components. During the 24-hour simulated storm event the highest TSS removal was achieved by BAM 2 & 3 which were both composed of 50% AASHTO A-3 sand with 1.8% silt/clay. This may indicate that in upflow BAM BMPs, total coliform removal is achieved via sorption rather than inert filtration. However, the generation of suspended solids due to sloughing biofilm in the columns may have obscured a relationship between total coliform removal and the removal of influent supplied TSS. Additionally, the generation of suspended solids via sloughed biomass may have also obscured which BAM type was the most effective at removing TSS that was in the influent.

Upflow BAM filters were shown not to be an acceptable method of HPC removal. All BAM types resulted in an increase in HPC during at least one, if not both, EBCTs due to the colonization of heterotrophic bacteria on the BAM, with greater increases corresponding to greater EBCT. Colonization of heterotrophic bacteria in the BAM is desirable because it is a component of nitrogen removal, a common performance goal of BAM systems. The increases in HPC concentration were a strong indicator of a portioned of sloughed biomass exiting the system in the effluent. If HPC is a parameter of concern for the stormwater BMP effluent, such as it being an influent supply for a membrane treatment drinking water plant, then an additional downstream disinfection treatment may be necessary.

CHAPTER 5: NITROGEN REMOVAL UTILIZING UPFLOW BAM FILTERS FOR THE APPLICATION OF TREATING STORMWATER IN A LOW-FOOTPRINT ULTRA-URBAN ENVIRONMENT

Abstract

Nitrogen is often the limiting nutrient for marine systems and its removal is a common primary target for stormwater best management practices (BMPs) [5]. Traditional BMPs, such as retention/detention treatment ponds require large footprints and may not be practical in ultra-urban environments. Upflow filters utilizing biosorption activated media (BAM) that can be placed underground offer a small footprint alternative. This paper seeks to determine if BAM, without an added biodegradable organic carbon component, is efficient in treating stormwater with low organic carbon for nitrogen. This research simulated stormwater that had already been treated or solids removal; thus, the nitrogen in the influent was assumed to be mostly non-settable suspended solids or dissolved. Three different BAM mixtures in a bench scale upflow filter configuration were compared for the parameters of total nitrogen and various nitrogen species. Furthermore, through nitrogen balance and polymerase chain reaction (PCR) amplification of target Anammox DNA, it was sought to determine if denitrification was primarily accomplished via anoxic chemoheterotrophic means or by endogenous denitrification and/or Anammox.

It was found that there was insufficient organic carbon consumption for heterotrophic denitrification utilizing influent supplied organic carbon substrate to account for the observed nitrogen removal. Furthermore, the PCR analysis confirmed the presence of Anammox bacteria

in all BAM types. Based on a detailed nitrogen mass balance, Anammox and endogenous denitrification were found to both be significant contributors to biological nitrogen removal, with Anammox being the dominant mechanism. Physical filtration and sorption were also significant factors in nitrogen removal. The best performing BAM mixture was able to achieve total nitrogen removal efficiencies of 23% and 50% with EBCTs of 22-minute and 220-minute respectively.

Keywords: biosorption activated media; BAM; stormwater; bio-filtration; tire crumb; expanded clay; nitrogen; water quality; sustainability; highway runoff; best management practice; BMP; Bold & Gold; Anammox; sorption; adsorption; denitrification; nitrite; ammonia; ammonium; nitrate; endogenous denitrification; biofilm; stormwater

Introduction

Stormwater runoff from roads often has elevated levels of nitrogen [6]. According to the National Oceanic and Atmospheric Administration (NOAA) the most common single factor causing eutrophication is an increase in the concentrations of the limiting nutrients nitrogen and phosphorus [10]. Typically, the primary limiting nutrient for plant and algal growth in marine ecosystems is nitrogen; thus nitrogen is of particular interest in coastal regions that discharge to marine estuaries or the ocean [5]. Traditional treatment best management practices (BMPs), such as detention basins and swales, require large amounts of available surface area and are therefore not always suitable for use in an ultra-urban environment constrained by a lack of available surface area. The term “ultra-urban BMP” is associated with the use of BMPs, sometimes proprietary, that have small footprints and are installed underground. In an ultra-urban environment, the use of traditional treatment BMPs such as detention basins and swales are constrained by the lack of available surface area. Thus, an inline or offline upflow filter utilizing Biosorption Activated Media (BAM) that could be installed underground would be a desirable BMP system [27, 48, 76]. While phosphorus can readily be removed through sorption or flocculation, nitrogen removal typically requires biological transformations in addition to sorption and filtration.

An ideal implementation of an upflow BAM filter system would be after the stormwater has already been treated by a solids removal system such as a baffle box, vortex separator, or stormwater pond. The removal of solids prior to entering the BAM upflow filter will prevent clogging thus extending the service life. This research simulated stormwater that had already been treated for solids removal; thus, most of the nutrients and solids in the simulated stormwater influent were likely as non-settable suspended solids or dissolved solids.

The BAM analyzed in this research is made of various components including tire crumb, expanded clay, AASHTO (American Association of State Highway and Transportation Officials) A-3 sand with 7.1% silt/clay, AASHTO A-3 sand with 1.8% silt/clay, and limestone screenings. Tire crumb and clay both have sorption properties, sand has physical filtration abilities, and limestone can be used for flocculation [35, 51, 52, 55, 59, 60, 109]. See APPENDIX I for a brief explanation of the AASHTO soil classification system.

Expanded clays are typically composed of an inert ceramic particle with a porous coating. Expanded clay is created by a process known as calcination which involves exposing the clay to temperatures of up to 1200°C inside a rotary kiln [62, 83]. During calcination the organic matter in the clay expands resulting in a high porosity, low bulk density aggregate. Furthermore, the expanded clay has a higher hydraulic conductivity (aka permeability) than similarly sized gravels and sands [62]. Expanded clay is also a known sorbent of ammonia[83].

Nitrogen in stormwater is composed of various forms including ammonia, organic nitrogen (both particulate and dissolved), nitrite, and nitrate. Nitrogen behavior and removal in BAM systems can be complex due to its many forms, nitrogen cycle transformations, and various removal mechanisms. Organic nitrogen can be captured via physical filtration and sorption [35]. Organic nitrogen can also be transformed into ammonia via ammonification, a type of mineralization [53, 61, 110]. Ammonia can be removed via ion exchange and sorption to materials such as activated carbon and tire crumb, although efficiency of this process has a wide range of reported results; literature suggests that clay also may be effective at removing ammonia in the 6-8 pH range [35, 51, 53, 54, 59, 60]. Under aerobic conditions, ammonia will undergo nitrification where it is biologically transformed into nitrite by chemoautotrophic ammonia oxidizing bacteria (AOB) and then into nitrate by chemoautotrophic nitrite oxidizing bacteria (NOB) [38]. The AOB and NOB steps of nitrification are shown in Equations (2) and (3), with the overall total reaction shown in Equation (4) [38]. Under anoxic conditions, nitrate and nitrite are dominantly removed via biological processes of the nitrogen cycle, due to the low efficiency of sorption of nitrate and nitrite [59]. Anoxic conditions are defined as DO levels below 0.2 mg/L; DO levels above 0.2 mg/L can inhibit denitrification [38, 40].

$$2NH_4^+ + 3O_2 \rightarrow NO_2^- + 4H^+ + 2H_2O \qquad (2)$$

$$2NO_2^- + O_2 \rightarrow 2NO_3^- \qquad (3)$$

$$NH_4^+ + 2O_2 \rightarrow NO_3^- + 2H^+ + H_2O \quad (4)$$

Under anoxic conditions, nitrate can be converted to nitrogen gas via chemoheterotrophic denitrification; however, this process requires biodegradable organic carbon so either biodegradable organic carbon must be available in the influent or it is obtained via endogenous chemoheterotrophic denitrification, where cells are broken down for their carbon [38, 42]. In anoxic, low organic carbon conditions, ammonia and nitrite can be removed via anaerobic ammonium oxidation (Anammox) [42, 111]. In this paper chemoheterotrophic denitrification utilizing biodegradable organic carbon from the influent shall be referred to as chemoheterotrophic denitrification utilizing organic substrate; endogenous chemoheterotrophic denitrification shall be referred to as simply endogenous denitrification.

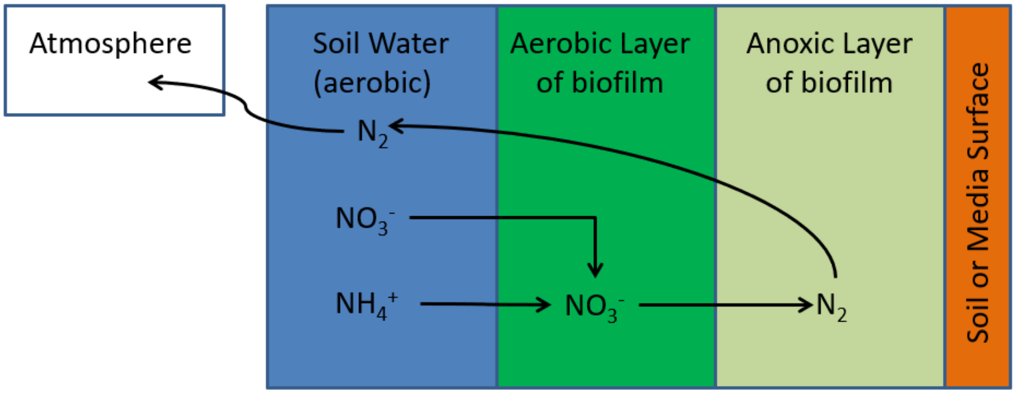
It has been demonstrated in various research projects that nitrogen can be removed from stormwater using BAM in various BMP configurations [27, 76, 112]. However, stormwater is known for having low organic substrate compared to wastewater [14, 15, 18]. The average total organic carbon (TOC) concentrations for freeway runoff and medium domestic wastewater are 9.13 mg/L as C and 140 mg/L as C respectively [14, 15]. Furthermore, due to the plug flow configuration of many stormwater treatment systems, organic carbon may be consumed at the start of the system in the aerobic zone before progressing to the anoxic zone [15, 18]. Chemoheterotrophic denitrification utilizing substrate occurs in the anoxic zone and requires organic carbon; so, if low concentrations of organic carbon are reaching the anoxic zone in plug flow reactors, then how is denitrification occurring? There are two main alternative pathways for denitrification that may be involved, endogenous denitrification and Anammox [38, 42]. Additionally, the autotrophic nitrifier *Nitrosomonas europaea* can utilize nitrite to oxidize ammonia under anoxic conditions, however its oxidation rate of ammonia is 6 to 10 times slower than that of Anammox, thus it is a minor contributor in comparison [38].

Anammox is a chemoautotrophic process performed by bacteria belonging to the phylum *Planctomycete* and more specifically the order *Planctomycetales* [38, 43, 44]. Anammox are obligate anoxic bacteria, meaning that they do not utilize oxygen as an electron acceptor. Anammox is a process that creates nitrogen gas by oxidizing ammonium (electron donor) with nitrite (electron acceptor). Nitrite also functions as an electron donor for the reduction of carbon dioxide and is oxidized to nitrate. The formula for Anammox is shown in Equation (5) [43-45]. Studies have shown that Anammox cannot efficiently use nitrate as an electron acceptor [42, 45].

$$\begin{aligned} NH_4^+ + 1.32\ NO_2^- + 0.066\ HCO_3^- + 0.13\ H^+ \\ \rightarrow 1.02\ N_2 + 0.26\ NO_3^- + 2.03\ H_2O + 0.066\ CH_2O_{0.5}N_{0.15} \end{aligned} \tag{5}$$

Since Anammox utilizes nitrite as an electron acceptor it must be coupled with AOB. However, the presence of NOB, which are also aerobic, compete with Anammox bacteria for the nitrite. Detailed discussions on the interaction and competition between AOB, NOB, and Anammox can be found in Kuenen, 2008 and Motlagh, 2014 [43, 45].

In addition to occurring in the bulk liquid anoxic zone of a plug flow reactor, chemoheterotrophic denitrification and Anammox can also occur in a micro-anoxic zone within the biofilm present in the bulk liquid aerobic zone of the reactor due to the aerobic-anoxic interface that occurs. The outer layer of the biofilm will exist in the aerobic zone, but the inner layers of the biofilm may be devoid of oxygen and under anoxic conditions [38, 42, 46, 47]. Both AOB and NOB will inhabit the outer aerobic zone of the biofilm, however the AOB will take priority over the NOB for oxygen consumption due to NOB being dependent upon nitrite production by the AOB, assuming the influent has little to no nitrite present [45]. Furthermore, the supply of organic substrate from the bulk liquid to the inner anoxic layer of the biofilm is diffusion limited and there may be inadequate organic substrate for chemoheterotrophic denitrification utilizing organic substrate, especially given that stormwater commonly contains low organic carbon concentrations when compared to wastewater, thus endogenous chemoheterotrophic denitrification may be occurring [15, 18, 46, 47]. The aerobic-anoxic interface and the process of chemoheterotrophic denitrification in biofilm is illustrated in Figure 15. The inner anoxic layer of the biofilm may be undergoing one or some combination of chemoheterotrophic denitrification utilizing influent supplied organic substrate, endogenous respiration (which would possibly lead to sloughing of the biofilm), and autotrophic Anammox which does not need organic carbon substrate [38, 42, 45, 46, 113-115]. The aerobic-anoxic interface and the process of Anammox in biofilm is illustrated in Figure 16. In a study by Helmer, 2001 a single stage nitrification/Anammox biofilm reactor was analyzed at DO concentration of 0, 0.7, 2.0, and 5.0 mg/L [42]. A DO concentration of 2.0 mg/L yielded the greatest net decrease in total inorganic nitrogen and a DO 0.7 mg/L allowed for a balance of nitrification and Anammox in the biofilm that did not add nitrite to the water [42].



Note: Organic carbon source not shown, may be either organic substrate or endogenous.

Figure 15: Chemoheterotrophic Denitrification in the Biofilm

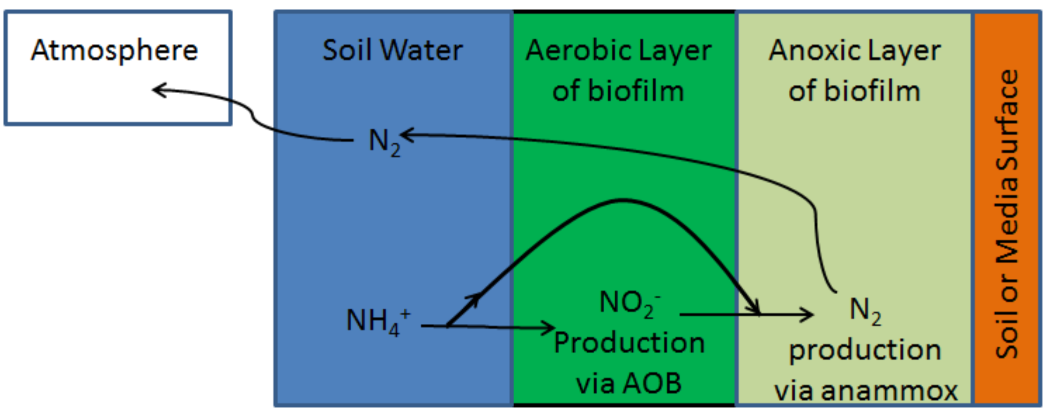


Figure 16: Anammox in Biofilm

The objective of this research was to develop a bench scale upflow filtration system that utilized biosorption activated media (BAM) for the treatment of ultra-urban stormwater runoff with the goal of improving the water quality of the runoff by the removal of the limiting nutrient nitrogen; furthermore, it was of interest if Anammox was a significant contributor to the nitrogen removal process. Three different BAM mixtures were evaluated for nitrogen removal performance. Mass balances were performed to determine the total nitrogen removal due to physical/chemical process such as sorption and filtration vs biological removal. Furthermore, mass balances were used to determine how much biological total nitrogen removal could be attributed to chemotrophic denitrification utilizing available influent organic carbon, endogenous denitrification, and possibly Anammox. Polymerase chain reacting (PCR) testing was done to determine qualitatively if Anammox bacteria were present.

Methods

Experimental Design

The configuration of the system was an upflow system, which was intended to reduce clogging potential due to fluidization of the media during flow. Additionally, the upflow system remained saturated during inter-storm periods, thus encouraging anoxic nitrogen cycle processes during inter-storm events. The experimental design analyzed three types of BAM mixes, the various components of which were: 50/50 volumetric ratio blend of course and fine expanded clay (hence forth referred to as 50/50 expanded clay), ⅜-inch expanded clay, automobile tire crumb (1–5 mm), limestone screenings, and American Association of State Highway and Transportation Officials (AASHTO) classification A-3 sand with 1.8% silt/clay and A-3 sand with 7.1% silt/clay. A brief description of the AASHTO soil classification system as well as particle size distribution curves for the BAM mixes and the individual components can be found in APPENDIX I.

The compositions of the three BAM types analyzed in this research are presented in Table 22. The permeability constant, dry density, and dry mass of each BAM type analyzed are presented in Table 23. BAM #1 had the advantage of a very high permeability constant and thus required much less driving head to maintain a given flow rate when compared to the other BAM. Furthermore BAM #1 primarily focused on sorption by having the highest tire crumb and cumulative expanded clay content. However, BAM #1 might not be expected to perform well for filtration by straining due to its larger particle sizes. BAM #2 focused on physical filtration by having a high ratio of small particle size media, specifically the AASHTO A-3 sand with 1.8% silt/clay and AASHTO A-3 sand with 7.1% silt/clay; BAM #2 also focused on sorption via the ⅜-inch expanded clay. BAM #3 utilized several removal mechanisms including physical filtration (note the 50% AASHTO A-3 sand with 1.8% silt/clay), flocculation using limestone screenings, and sorption via tire crumb and 50/50 expanded clay [35, 51, 52, 55, 59, 60, 109]. Furthermore, all BAM types analyzed were expected to utilize varying degrees of biological processes to aide in nitrogen removal.

Table 22: BAM Compositions

BAM #	50/50 Expanded Clay	3/8 inch Expanded Clay	Tire Crumb	A-3 sand with 1.8% silt/clay	A-3 sand with 7.1% silt/clay	Limestone Screenings
1	55%	20%	25%	0%	0%	0%
2	0%	25%	0%	50%	25%	0%
3	15%	0%	15%	50%	0%	20%

Note: Percentages were as loose, uncompacted volumetric ratios.

Table 23: BAM Characteristics

BAM #	Permeability constant (in/hr)	Dry Density of BAM in Column (kg/m^3)	Dry Mass of BAM in Column (kg)
1	475.25	579.6	2.9
2	6.733	1242.5	6.1
3	12.86	1246.4	6.2

The bench-scale experiment consisted of three sets of columns, each set with a different media type (1, 2, and 3), see Table 22. Each set of columns consisted of three columns (A, B, and C), for a total of nine columns, see Table 24. All the columns had an internal diameter of 4 inches. The media occupied 2 feet of each column (see Figure 17). The A and B columns were duplicate columns with a single type of BAM. The C columns had the same BAM plus it received a nitrification inhibitor, 2-Imidazolidinethione, at a concentration of 10 mg/L in the influent. The purpose of the nitrification inhibitor in the C columns was to confirm nitrification was occurring and to enable an analysis to estimate the amount of organic nitrogen and ammonia that is being removed via the physical/chemical process of filtration and sorption. See APPENDIX N for a more detailed description of the system design.

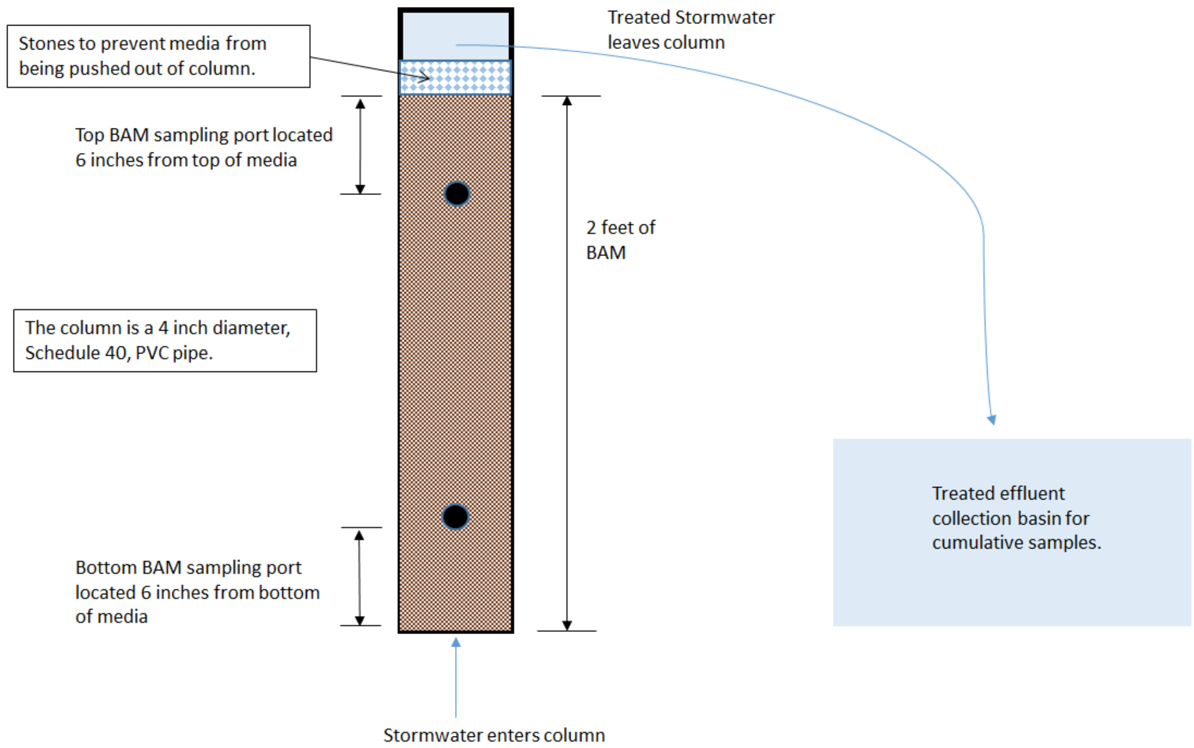


Figure 17: Upflow Column Design

Table 24: Column Types

Column Type	Description
A	BAM #
B	BAM # (duplicate of A)
C	BAM # + Nitrification Inhibitor in influent

Operation of columns

The simulated stormwater runoff was obtained by spiking water from a stormwater pond with ammonium carbonate, potassium nitrate, and potassium phosphate in order to approximately reach the average highway runoff concentrations for nitrogen and phosphorus species listed in the National Stormwater Quality Database (NSQD), see Table 25 [18]. Actual influent values for each parameter varied due to seasonal variations and other environmental factors affecting the pond. The column operations simulated 2 and 24-hour storm events over an 8 month period.

Table 25: Average Concentrations of Pollutants in Freeway Runoff from the NSQD [18]

Pollutant	National Freeway Runoff Concentrations
NH_3	1.07 mg/L as N
TKN	2.0 mg/L as N
$NO_2^- + NO_3^-$	0.28 mg/L as N
Total Nitrogen	2.28 mg/L as N
Filtered Phosphorus	0.20 mg/L as P
Total Phosphorus	0.25 mg/L as P
pH	7.10
Total Suspended Solids (TSS)	99.0 mg/L

Since the simulated stormwater was obtained from a pond, most of the settable solids had already been removed; the NSQD average TSS for freeway runoff is 99 mg/L whereas the average influent TSS to the BAM columns was 4.75 mg/L and 3.00 mg/L for the 22-minute and 220-minute EBCTs respectively. Additionally, since dissolved forms of nitrogen and phosphorus were used to spike the pond water for nutrient content, it can be assumed that most of the nutrients are either as dissolved or non-settable suspended solids. Thus, the simulated stormwater represents stormwater that had been already treated for solids removal by a baffle box or pond and the remaining nutrient content is mostly as dissolved or non-settable suspended solids.

The column operations simulated 2- and 24-hour "storm events". There were three 2-hour storm events per week and one 24-hour, lower intensity, storm event per week. Sampling events occurred twice a week, once for a 2-hour storm event and once for a 24-hour storm event. The columns were operated for 5.5 months before analyses for nutrient performance and nutrient balances were started. This was done to allow the biofilm to mature and for the columns to reach steady state conditions with regards to nutrient removal and transformations. Samples were taken periodically during the non-analysis time frame to monitor the system for steady state nutrient removal conditions.

Based on the dimension for each column (a diameter of 4 inches and a height of 24 inches), the total volume was 302 in^3 and cross-sectional area of 12.57 inches. The Empty Bed Contact Time (EBCT) and hydraulic loading rates were calculated from the actual volume of effluent collected from each column. There was little column to column variation for the EBCT and hydraulic loading rates for both the 2 and 24 hour rates respectively; the average EBCT for the 2 hour storm event was 22 minutes and the average EBCT for the 24 hour storm event was 220 minutes, see Table 26.

Table 26: EBCT, Hydraulic Residence Time, & Hydraulic Loading Rate

Flow Duration (hours)	EBCT (minutes)	Hydraulic Load per unit volume of media "1/hour" (in^3 water / hour) / (in^3 of media)	Hydraulic Load per cross -sectional area (aka the flux) (gallons water / minute) / (ft^2 of cross section)
2	22	2.723	0.679
24	220	0.273	0.068

Water sampling and PCR

Nutrient, and TOC samples

Effluent stormwater from each column was collected as a cumulative sample at the end of the testing event. The influent and effluent water samples were then sent to a NELAC (National Environmental Laboratory Accreditation Conference) certified laboratory for nitrate plus nitrite (NO_x), total nitrogen (TN), and ammonia analysis. In addition to nitrogen species samples, total organic carbon (TOC) and dissolved oxygen (DO) samples were also taken from the influent and effluent. Phosphorus, HPC, E. coli, and total coliform data were analyzed as discussed in Chapters 3 and 4.

PCR

A polymerase chain reaction (PCR) is a method for amplifying a specific DNA target sequence to a concentration where it can be detected via electrophoresis using a 2% Agarose ethidium bromide gel. This method was used to determine if Anammox bacteria were present in the upflow BAM systems. Primers for Anammox bacteria were selected from those reported in the literature; the primers utilized, as well as their annealing temperatures, are presented in Table 27. The thermocycle utilized is presented in Table 28.

Table 27: PCR Primers

Target Gene	Primer Name	Primer Sequence (5'→3')	Melt Temperature °C	Annealing Temperature °C	Product length (base pairs)	Literature Source
Anammox (amx)	Amx-F (Pla46F)	GGATTAG GCATGCA AGTC	50.9	46	621	[116]
	AMX667R	ACCAGAA GTTCCACT CTC	50.8			

Table 28: Anammox PCR Thermocycle

	Stage	Temperature °C	Time
	Initial Denature	95	1 minute
45 cycles	Denature stage	95	30 seconds
	Annealing stage	46	30 seconds
	Elongation stage	68	45 seconds
	Final Extension	68	5 minutes
	Hold	18	2 minutes

BAM samples were collected from access ports located 6 inches from the bottom of the media and 6 inches from the top of the media, see Figure 17. The BAM samples were removed from the pilot plant columns using autoclaved metal spatulas. The BAM was stored in sterile, 50 mL conical centrifuge tubes in a -80°C freezer until extraction.

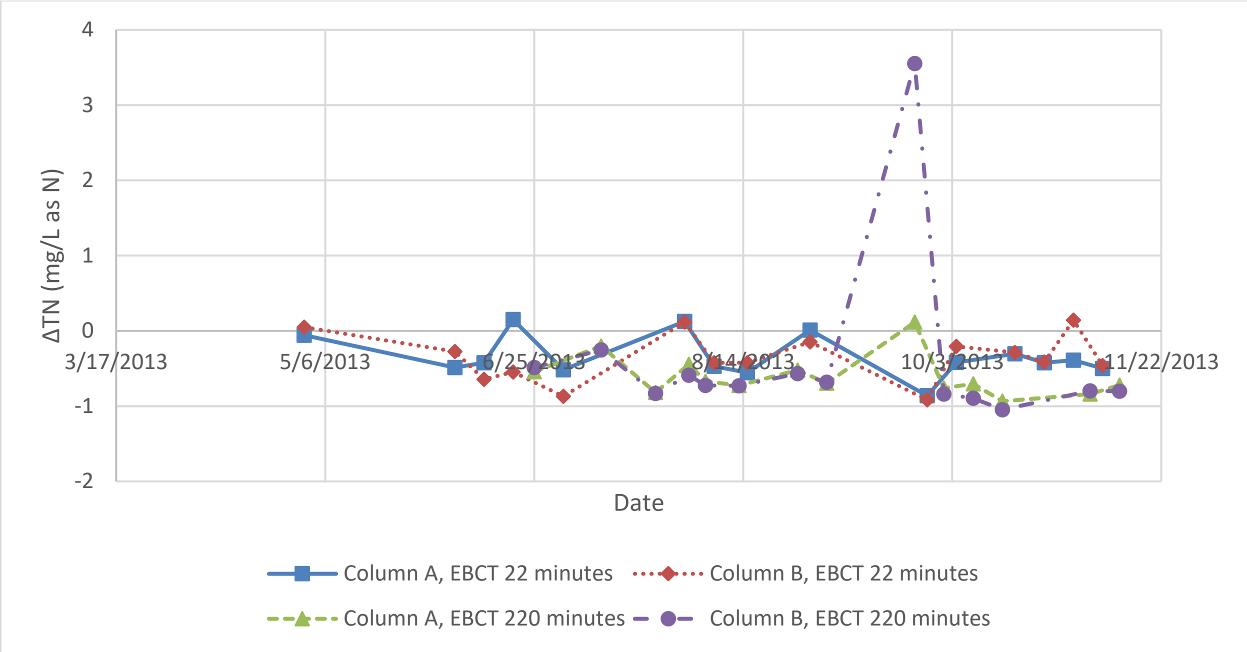
The DNA was extracted from the BAM utilizing the <u>PowerMax® Soil DNA Isolation Kit</u> by MO BIO Laboratories (Carlsbad, CA); an alternative extraction protocol provided by MO Bio was used due to the high clay content of the media (see APPENDIX H). The extracted DNA was then cleaned to remove PCR inhibitors by using the <u>PowerClean® Pro DNA Clean-Up Kit</u>

by MO BIO Laboratories. Qualitative testing for the presence/absence of Anammox was done using 2% agarose ethidium bromide gels.

Results & Discussion

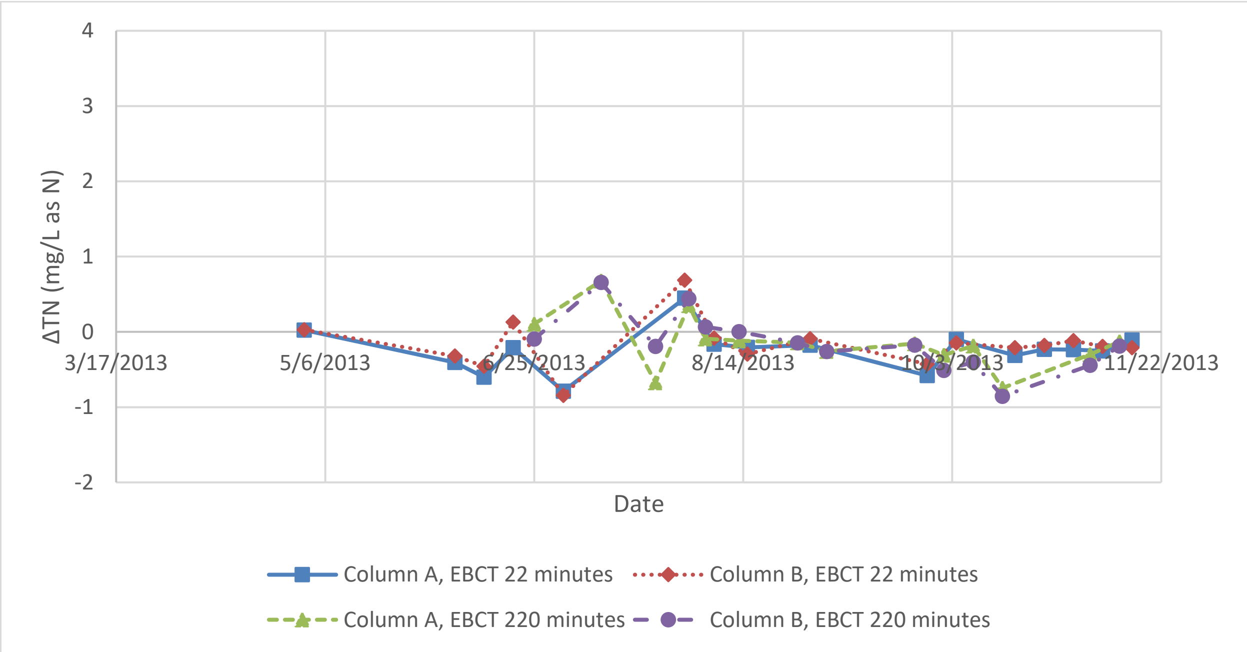
Comparison of Duplicate A & B Columns

Each BAM type had A and B duplicate columns. The duplicate columns had two purposes, first to increase the sample size when determining the average performance and second to allow for a comparison of variability between two identical BAM BMPs to see if the nutrient performance was generally the same given identical conditions on a per event basis. Graphs showing the values for change in Total Nitrogen (TN), ammonia, and NOx on dates when data was collected from both A & B Columns are presented in Figure 18, Figure 19, Figure 20, Figure 21, Figure 22, Figure 23, Figure 24, Figure 25, and Figure 26. The A and B columns for each BAM type tend to perform similarly on any given day for the parameters of TN, NH_3, and NOx, thus indicating that the influent composition has a large effect on the performance and that the expected performance for an upflow BAM system is repeatable for a given influent. Significant differences in change in concentration between the A & B columns, such as seen in Figure 18 for the 220-minute EBCT on 9/24/2013, may be due to biofilm sloughing. Sloughing has been documented to occur in denitrifying biofilms due to the formation of nitrogen bubbles at the base of biofilms [113, 115]. Sloughing may also occur due to endogenous denitrification occurring at the base of the biofilm due to the lack of organic carbon permeating through the depths of the biofilm; the endogenous respiration of the biofilm at its base may cause the biofilm to break free. [113, 114, 117].



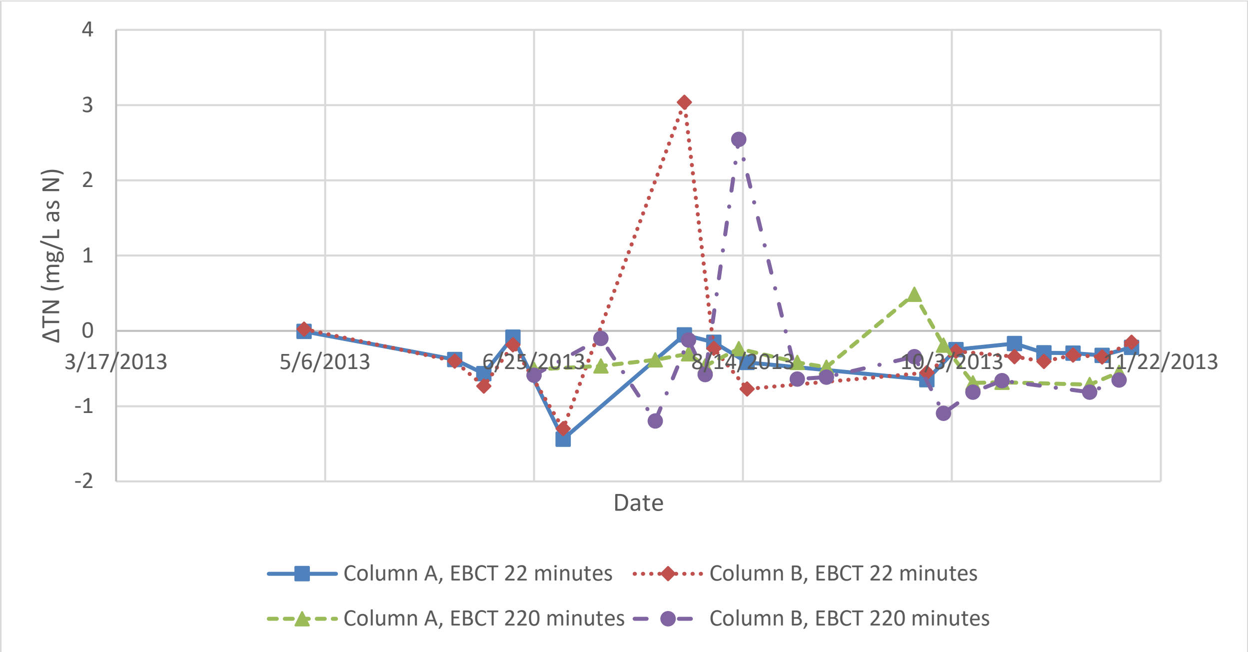
Note:
Δ = Effluent – Influent; thus, a positive Δ indicates an increase and a negative Δ indicates a decrease.

Figure 18: BAM #1 ΔTN of Columns A & B



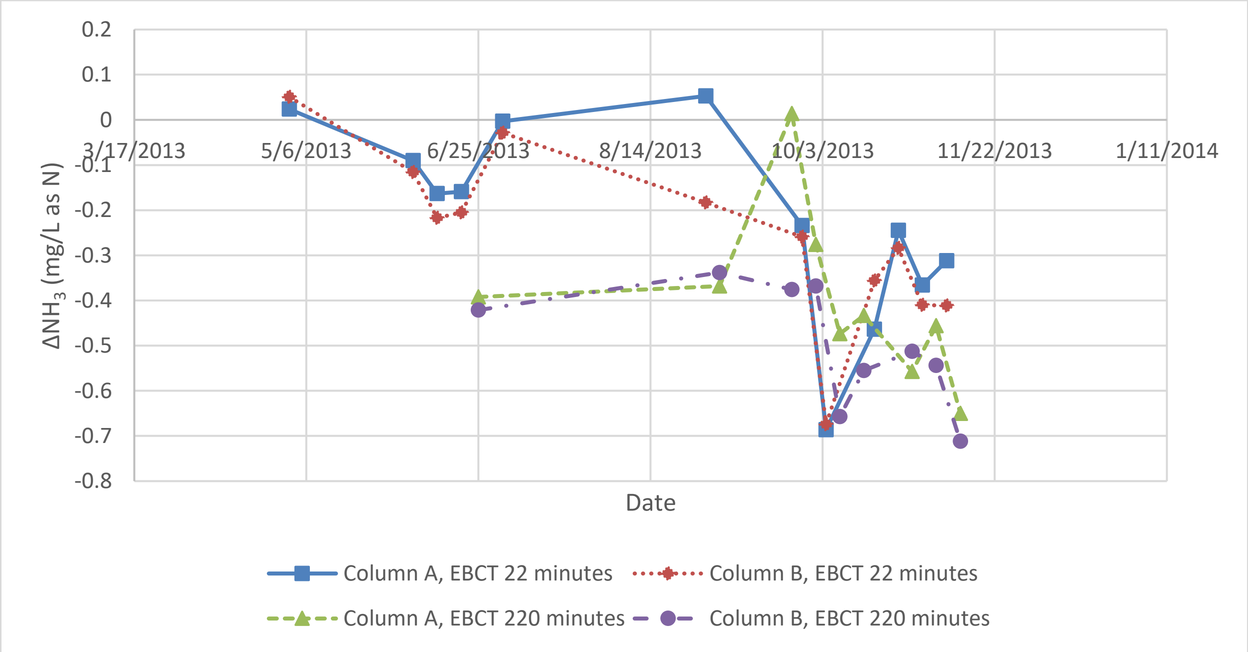
Note:
Δ = Effluent – Influent; thus, a positive Δ indicates an increase and a negative Δ indicates a decrease.

Figure 19: BAM #2 ΔTN of Columns A & B



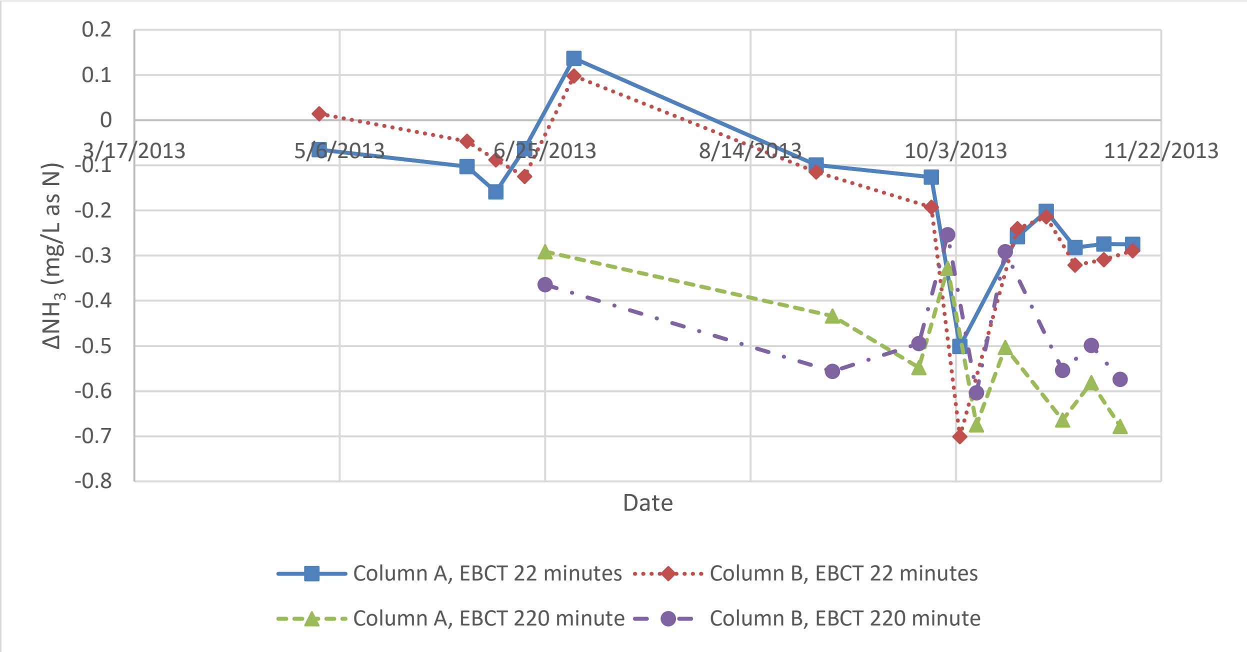
Note:
Δ = Effluent – Influent; thus, a positive Δ indicates an increase and a negative Δ indicates a decrease.

Figure 20: BAM #3 ΔTN of Columns A & B



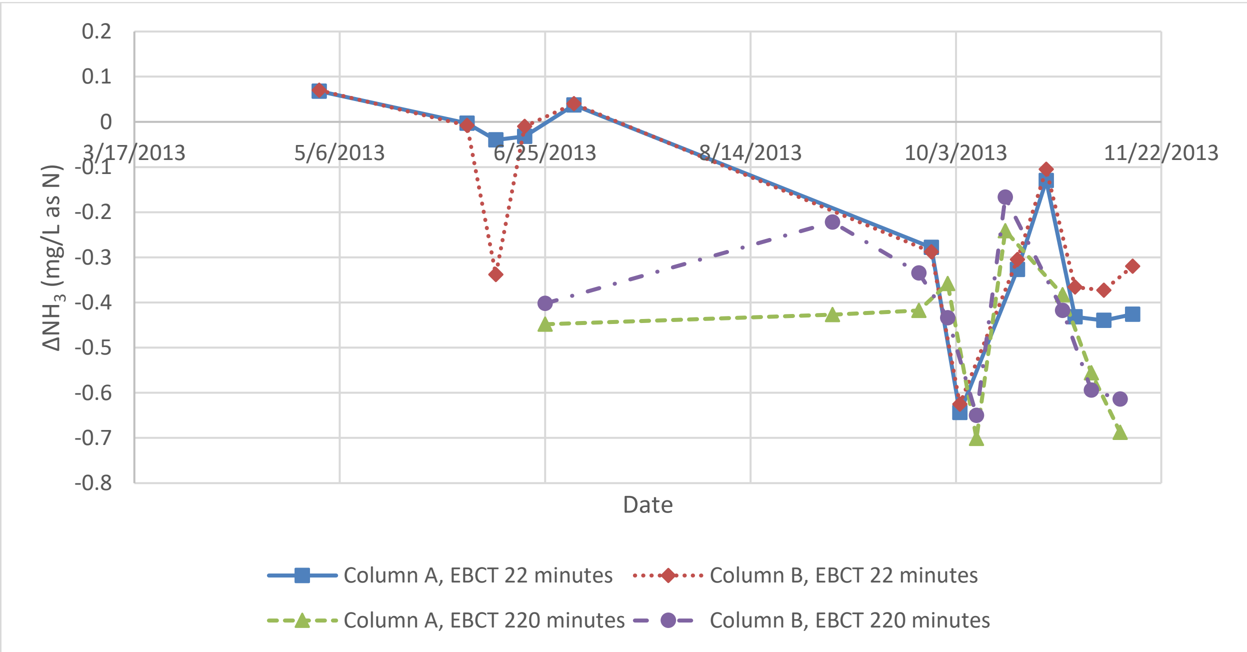
Note:
Δ = Effluent – Influent; thus, a positive Δ indicates an increase and a negative Δ indicates a decrease.

Figure 21: BAM #1 ΔNH_3 of Columns A & B



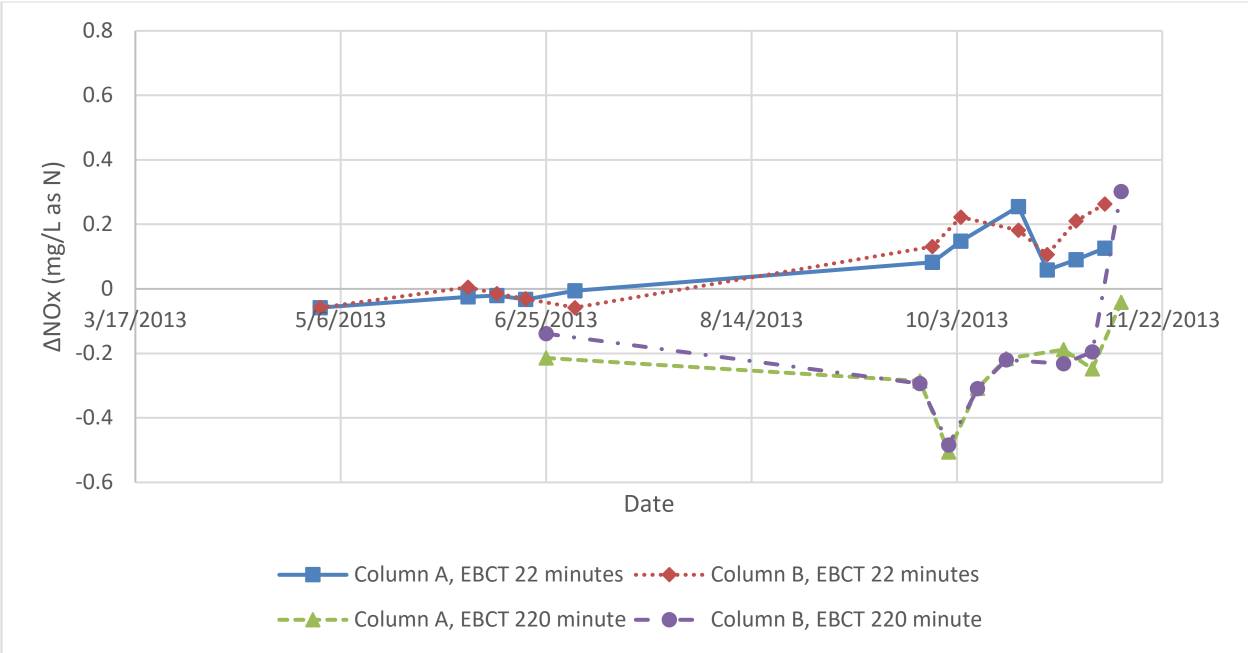
Note:
Δ = Effluent – Influent; thus, a positive Δ indicates an increase and a negative Δ indicates a decrease.

Figure 22: BAM #2 ΔNH_3 of Columns A & B



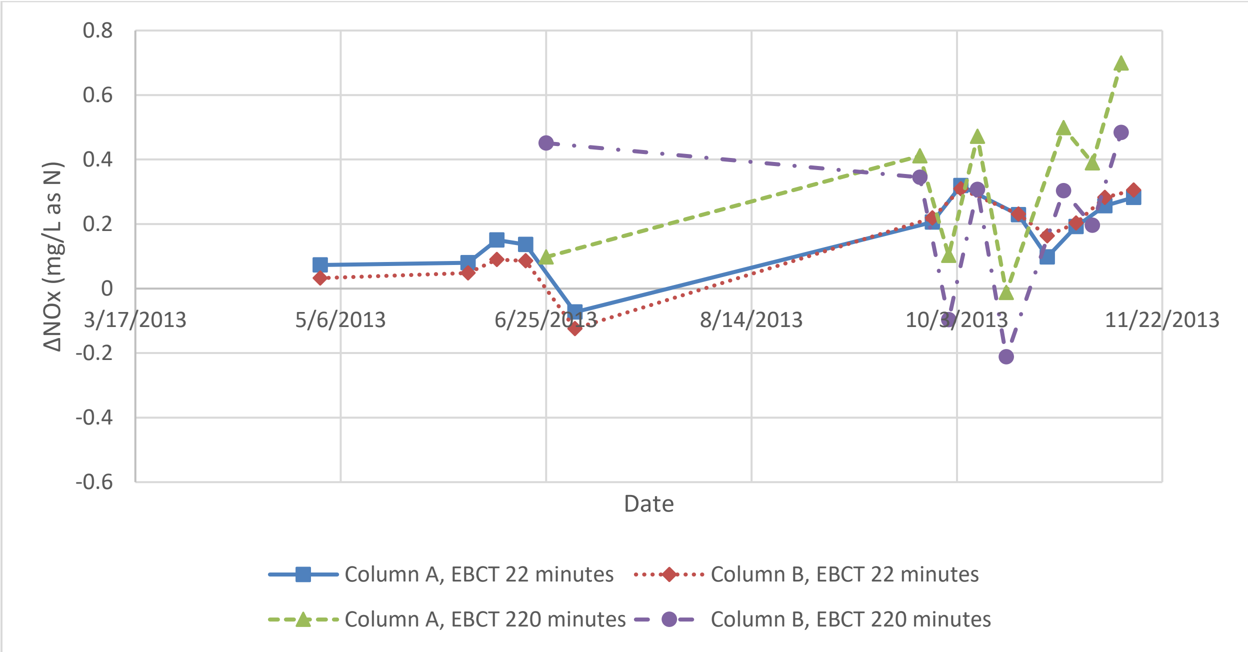
Note:
Δ = Effluent – Influent; thus, a positive Δ indicates an increase and a negative Δ indicates a decrease.

Figure 23: BAM #3 ΔNH_3 of Columns A & B



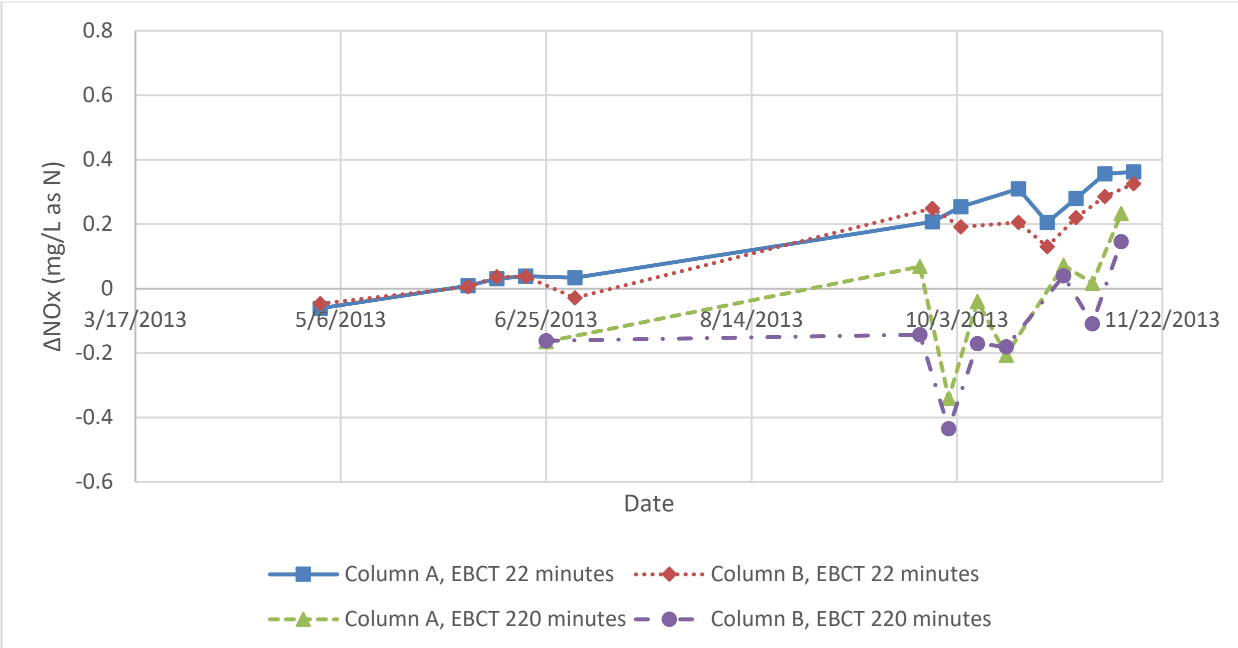
Note:
Δ = Effluent – Influent; thus, a positive Δ indicates an increase and a negative Δ indicates a decrease.

Figure 24: BAM #1 ΔNOx of Columns A & B



Note:
Δ = Effluent – Influent; thus, a positive Δ indicates an increase and a negative Δ indicates a decrease.

Figure 25: BAM #2 ΔNOx of Columns A & B



Note:
Δ = Effluent – Influent; thus, a positive Δ indicates an increase and a negative Δ indicates a decrease.

Figure 26: BAM #3 ΔNOx of Columns A & B

Overall Nitrogen Species Performance of BAM Types

Total nitrogen is composed of both inorganic nitrogen (ammonia, nitrate, nitrite) and organic nitrogen [61]. The equations for inorganic and organic nitrogen are shown in Equations (6) and (7). Inorganic nitrogen is the form of nitrogen that is immediately available to algae and plants [110]. Additionally, organic nitrogen may degrade to ammonia via ammonification and become available as well; thus, removal of organic nitrogen is also of importance when treating stormwater [110].

$$Organic\ N = TN - NH_3 - \mathrm{NOx} \qquad (6)$$

$$Inorganic\ N = TN - Organic\ N = NH_3 + NOx \qquad (7)$$

The magnitude of the decrease in TN and inorganic nitrogen increased for all BAM types with increasing EBCT (Table 29). This was to be expected since both sorption and biological removal increase with increased contact time (Table 29). However, the decrease in organic nitrogen diminished for all BAM types with increase in EBCT (Table 29). Furthermore, during the 220-minute EBCT the BAM types with the two highest TN removals, BAM #1 and BAM #3, experienced the lowest organic nitrogen decreases (Table 29). An explanation is that as TN removal via denitrification increased, sloughing of biofilm also increased; biofilm sloughing due to denitrification in micro-anoxic zones has been well documented in the literature [113-115, 117]. Sloughed biofilm in the effluent would be detected as organic nitrogen. This explanation of sloughing biofilm is supported since the DO concentrations of the influents and effluents were all above 0.2 mg/L; thus the bulk water was in an aerobic state throughout the entire length of the columns (Table 31) [38]. Since the bulk water was aerobic, for significant denitrification to occur, it must have occurred in micro-anoxic zones of a layered biofilm as illustrated in Figure 15 and Figure 16 [38, 46].

BAM #1 had the highest total nitrogen (TN) and inorganic nitrogen removal of all the BAM types assessed for both the 22 and 220-minute EBCT (see Table 29). BAM #3 had the second best TN and inorganic removal rates for both the 22 and 220-minute EBCT (see Table 29). BAM #1 and BAM #3 were the only BAM types to contain tire crumb and 50/50 expanded clay. Tire crumb is a known sorbent for ammonia [35, 51, 53, 54, 59]. Expanded clay is also a known sorbent of ammonia and the small particle sizes of the 50/50 expanded clay creates a great amount of surface area for sorption to occur [83]. Furthermore, BAM #1 had the smallest increase in NOx during the 22-minute EBCT and was the only BAM to achieve a net decrease in NOx during the 220-minute EBCT, indicating that BAM #1 achieved a significant denitrification rate (Table 30). The decrease in NOx concentration by BAM #1 during the 220-minute EBCT indicates that denitrification of NOx was outpacing the formation of NOx via nitrification (Table 30). This is significant since ammonia and NOx, together known as inorganic nitrogen, are the forms of nitrogen that are immediately available to algae and plants [110].

Table 29: Summary of Nitrogen Performance

	BAM #	Influent TN (mg/L as N)	Δ TN (mg/L as N)	% Removal of TN	Influent Inorganic Nitrogen (mg/L as N)	Δ Inorganic Nitrogen (mg/L as N)	Influent Organic Nitrogen (mg/L as N)	Δ Organic Nitrogen (mg/L as N)
2-hour Duration (EBCT: 22 minutes)	1	1.600	-0.349	23%	0.908	-0.186	0.749	-0.138
	2	1.600	-0.210	14%	0.893	-0.033	0.749	-0.145
	3	1.600	-0.294	19%	0.893	-0.084	0.749	-0.178
24-hour Duration (EBCT: 220 minutes)	1	1.594	-0.801	50%	1.051	-0.739	0.572	-0.027
	2	1.594	-0.300	19%	1.051	-0.191	0.572	-0.101
	3	1.594	-0.551	37%	1.051	-0.455	0.572	-0.065

Note:
•Δ = Effluent – Influent, thus a positive Δ indicates an increase and a negative Δ indicates a decrease.
•% Removal= 100%*(Influent – Effluent)/Influent, thus a positive % Removal indicates removal occurred; a negative % Removal indicates that an increase occurred.

Table 30: Changes in Inorganic Nitrogen Species

	BAM #	Influent NH_3 (mg/L as N)	Δ NH_3 (mg/L as N)	Influent NOx (mg/L as N)	Δ NOx (mg/L as N)
2-hour Duration (EBCT: 22 minutes)	1	0.679	-0.361	0.238	0.150
	2	0.649	-0.275	0.237	0.242
	3	0.649	-0.373	0.237	0.280
24-hour Duration (EBCT: 220 minutes)	1	0.735	-0.513	0.308	-0.220
	2	0.735	-0.554	0.308	0.384
	3	0.735	-0.489	0.308	0.017

Note:
Δ = Effluent – Influent, thus a positive Δ indicates an increase and a negative Δ indicates a decrease.

Table 31: Dissolved Oxygen

	BAM #	Influent DO (mg/L as O_2)	Effluent DO (mg/L as O_2)
2-hour Duration (EBCT: 22 minutes)	1	4.7	1.9
	2	4.7	3.1
	3	4.7	2.0
24-hour Duration (EBCT: 220 minutes)	1	5.0	1.2
	2	5.0	0.8
	3	5.0	0.7

The exceptional nitrogen removal performance of BAM #1 was likely due to its high content of expanded clay and tire crumb compared to the other BAM types analyzed. Not only do these two types of media components serve as excellent sorption materials, but they also serve to provide a large amount of surface area for sorption and biofilm due to their macropores, mesopores, micropores, and submicropores [118]. Scanning electron microscope views of 50/50 expanded clay, tire crumb, and AASHTO A-3 sand with 1.8% silt/clay are shown in Figure 27, Figure 28, and Figure 29. Note the extremely porous nature of the expanded clay and tire crumb compared to the AASHTO A-3 sand with 1.8% silt/clay. The clay and tire crumb provided more surface area for a given particle diameter.

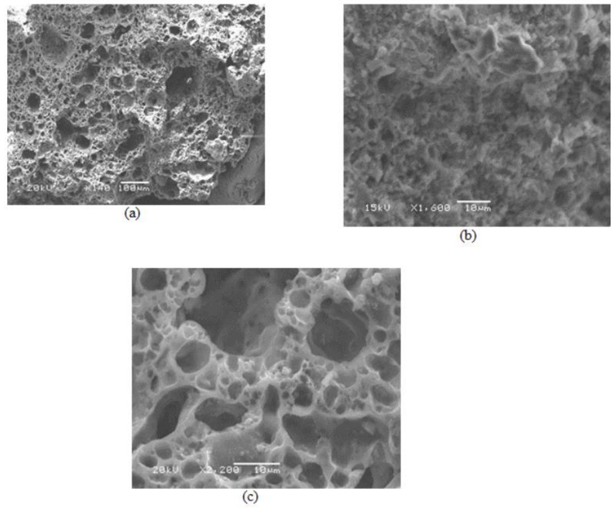


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Figure 27: 50/50 expanded clay shown in Scanning Electron Microscope (a) 140 X, (b) 1,600 X, (c) 2,200 X magnification [84, 85]

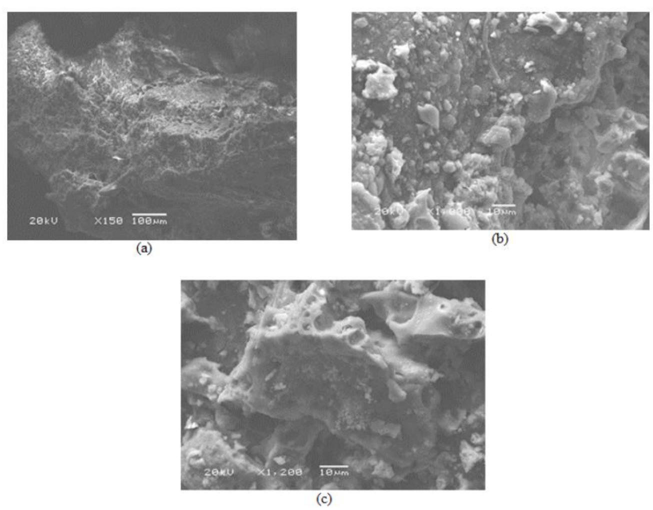

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Figure 28: Tire crumb shown in Scanning Electron Microscope(a) 140 X, (b) 1,600 X, (c) 2,200 X magnification [84, 85]

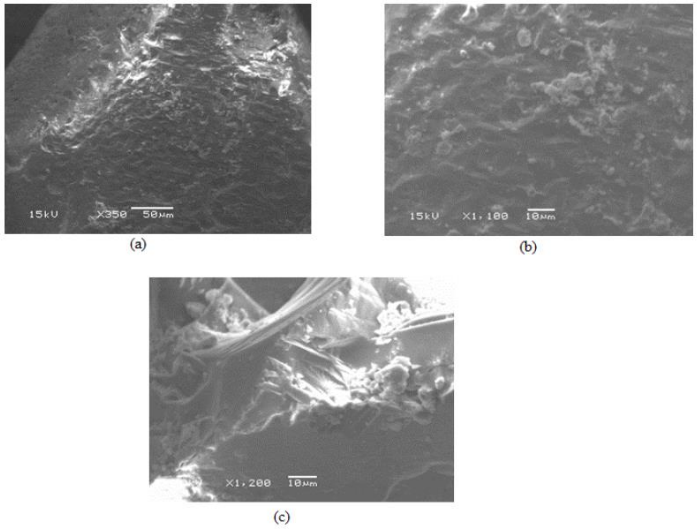

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Figure 29: Sand shown in Scanning Electron Microscope at (a) 140 X, (b) 1,600 X, (c) 2,200 X magnification [84, 85]

BAM #2 did not perform well in regard to nitrogen removal during either of the EBCTs. BAM #2 had the smallest TN removal and inorganic Nitrogen decrease during both EBCTs (Table 29). During the 22 minute EBCT, BAM #2 had the lowest ammonia decrease yet had the second highest increase in NOx; during the 220 minute EBCT BAM #2 had the highest ammonia decrease and highest increase in NOx; together this indicates that BAM #2 was not facilitating denitrification (Table 30). BAM #2 had the second lowest effluent DO concentration during the 220-minute EBCT which should have greatly aided in the formation of micro-anoxic zones in the biofilm, yet it had the greatest increase in NOx and lowest TN removal (Table 29, Table 30, Table 31). It can be concluded that BAM #2 did not encourage the growth of layered biofilm and the formation of micro-anoxic zones which were necessary for denitrification. BAM #2 is the only type that did not contain tire crumb or 50/50 expanded clay, both of which provide significant surface area for biofilm growth due to their rough surfaces (see Figure 27 and Figure 28). This was likely a contributing factor to its poor performance.

Nitrogen Removal: Physical/Chemical Filtration & Sorption vs Biological Processes

Nitrogen is removed in the BAM by physical/chemical filtration and sorption processes as well as biological processes. For the purpose of this paper, nitrogen removal by biological processes includes ammonification, nitrification, and denitrification, with the ultimate removal mechanism being either chemoautotrophic or chemoheterotrophic denitrification. Assimilation of nitrogen into the biomass was not considered a biological or physical/chemical filtration and sorption removal mechanism. It is assumed that the BAM upflow filters were in a steady state condition over time in terms of growth and sloughing of the biofilm [47]. Organic nitrogen associated with sloughed biofilm would either exit the system in the effluent, be removed via physical/chemical filtration and sorption processes, or undergo ammonification as shown in Figure 30.

In order to establish the amount of nitrogen removal due to physical/chemical filtration & sorption processes vs. biological processes, the change in organic nitrogen data from Columns A & B is combined with the change in ammonia data from Column C for each BAM type. The change in organic nitrogen value from the C Columns was not used due to the nitrification inhibitor, 2-imidazolidinethione, containing nitrogen as part of its chemical structure and thus itself being counted as a contributor to organic nitrogen. Based on the similar per event performance trends of the A & B columns discussed earlier in this paper, it is assumed that the C columns behaved similarly to the A & B columns with respect to ammonification, ammonia sorption, nutrient assimilation (biofilm growth), biofilm sloughing, and physical/chemical filtration and sorption of organic nitrogen. The nitrogen cycle that occurred in the A & B Columns is presented in Figure 30. Of note, according to the Sigma-Aldrich Safety Data Sheet, is that 2-imidazolidiethione is not readily biodegradable, thus it should not be expected to biologically break down into ammonia or NOx and should not exert a biological oxygen demand [119].

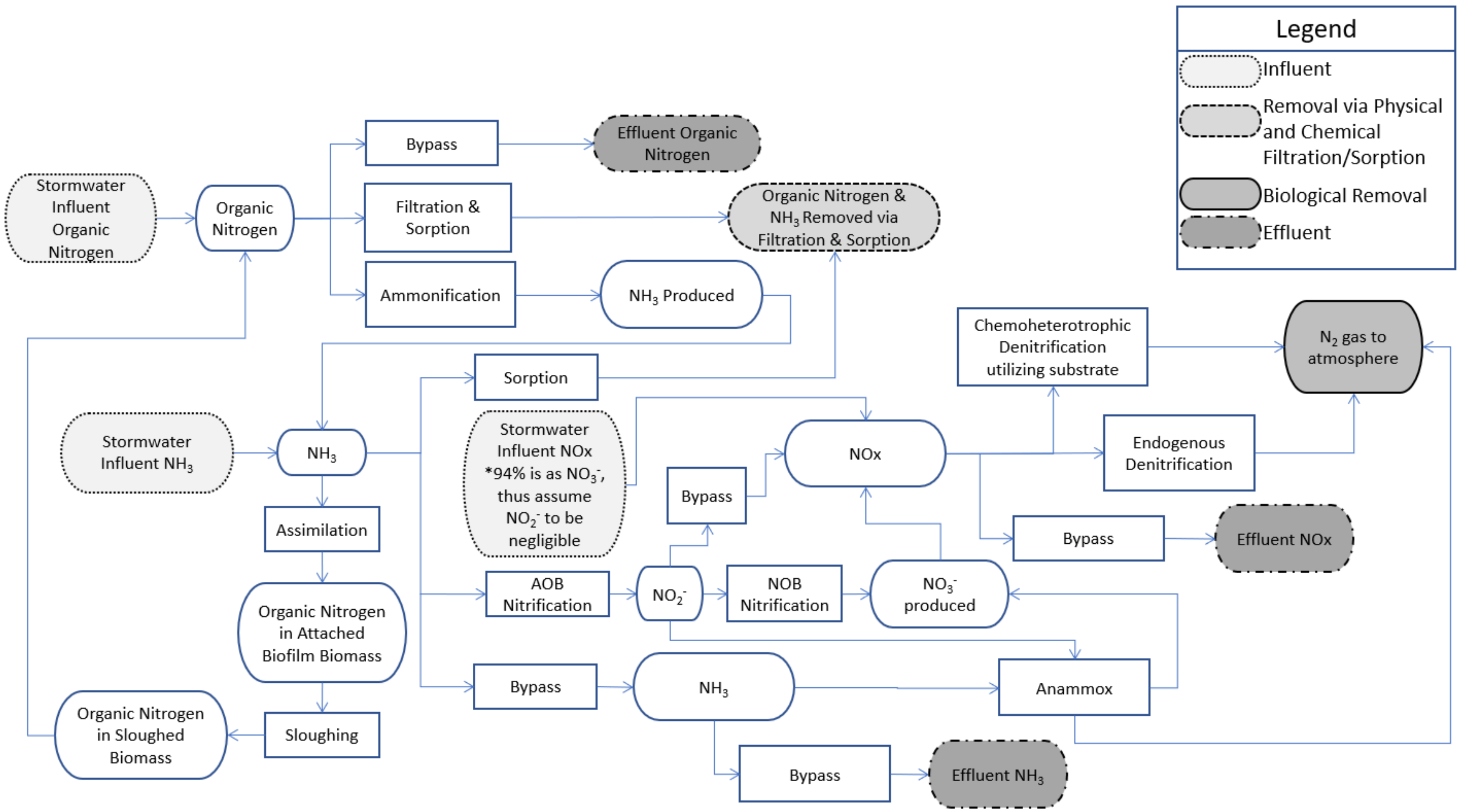

Figure 30: Nitrogen Cycle of A & B Columns

Nitrification inhibitor was added to the influent of the C columns, preventing transformation of ammonia into NOx. Additionally, early in the study, the influent stormwater was tested to see if nitrite was a significant component of the NOx in the influent. It was found that nitrite made up only 5.70% of the total NOx (see APPENDIX J). Thus, approximately 94% of the NOx was composed of nitrate. The insignificant amount of nitrite in the influent is important because Anammox directly utilizes nitrite to oxidize ammonia, not nitrate [42, 111]. Thus, it can be assumed that the removal of ammonia and NOx via Anammox in the C columns was negligible due to the negligible initial nitrite concentration and lack of additional nitrite production. The small amount of nitrite present is a reasonable representation since the NSQD median nitrite component of NOx for freeway runoff is 11% [14]. The nitrogen cycle that occurred in the C Columns is presented in Figure 31.

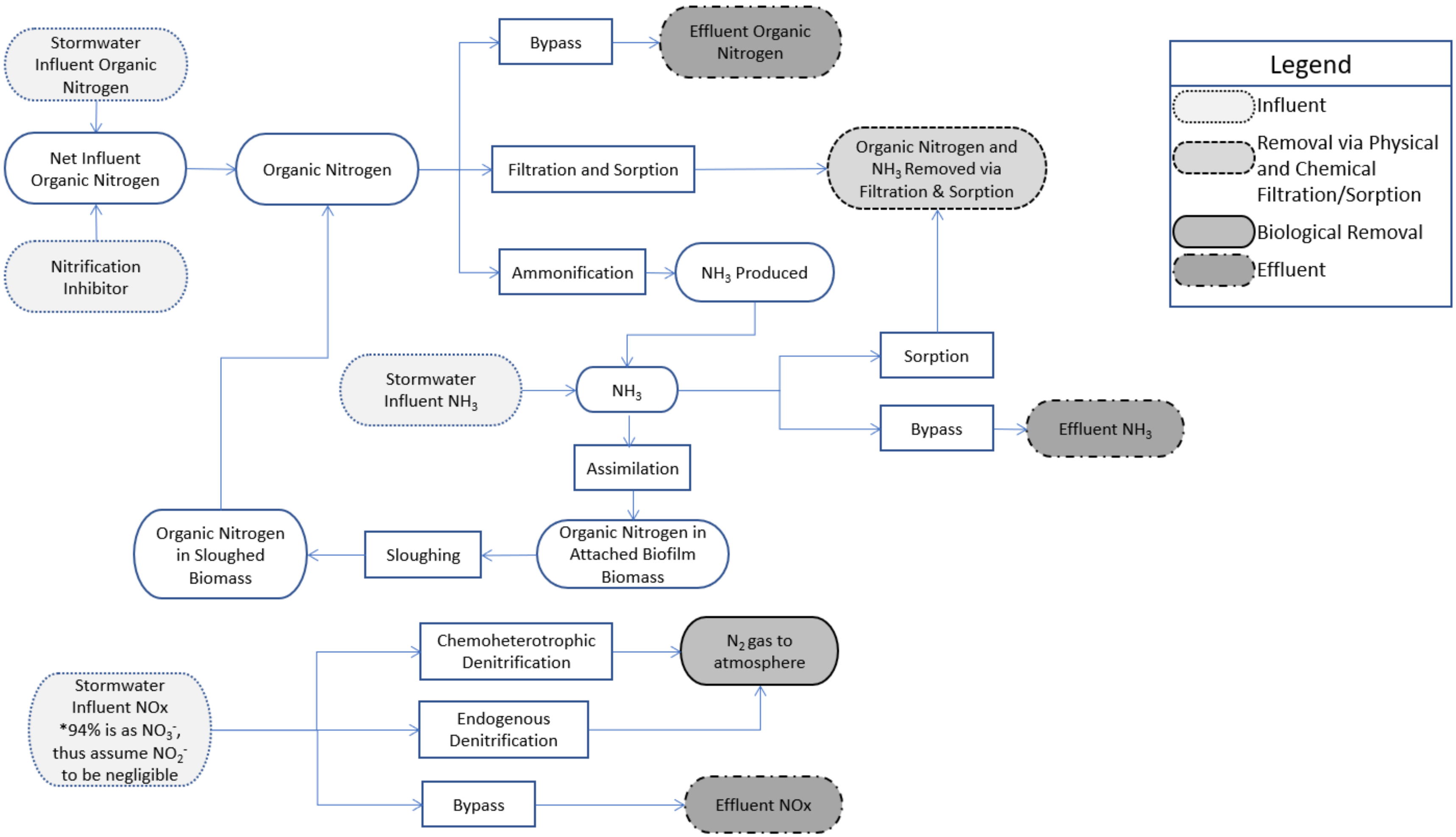

Figure 31: Nitrogen Cycle of C Columns

The average change in ammonia for both the A & B Columns and C Columns of each BAM type is presented in Table 32. For all BAM types, during both EBCTs, the A & B Columns experienced significant decreases in ammonia whereas the C Columns did not. This indicates that nitrification was indeed occurring in the A and B Columns and that the nitrification inhibitor present in the C Column influent was indeed preventing nitrification.

In Columns A & B, as illustrated in Figure 30, in addition to nitrification of ammonia occurring, ammonia was also likely being removed via sorption, and simultaneously being created via ammonification of organic nitrogen [35, 51, 53, 54, 59-61, 110, 120, 121]. Ammonification is the biological process of converting organic nitrogen to ammonia by organisms that are using the organic matter as an energy and nutrient source [61, 120, 121]. For the C Columns, the nitrification inhibitor prevented nitrification, thus the change in ammonia is due to the summation of removal of ammonia via sorption and the creation of ammonia via ammonification, as illustrated in Figure 31. During the 22-minute EBCT, the C Columns of BAM # 2 and BAM #3 experienced a small increase in ammonia, indicating that ammonification of organic nitrogen to ammonia was outpacing sorption of ammonia, see Table 32.

Table 32: Effect of Nitrification Inhibitor on Change in Ammonia

EBCT (minutes)	BAM #	Columns A & B ΔNH_3 (mg/L as N)	Column C ΔNH_3 (mg/L as N)
22	1	-0.361	-0.054
	2	-0.275	0.022
	3	-0.373	0.004
220	1	-0.513	-0.008
	2	-0.554	-0.028
	3	-0.489	-0.073

Note:
Δ = Effluent – Influent, thus a positive Δ indicates an increase and a negative Δ indicates a decrease.

The summation of the change in organic nitrogen data from A & B columns with the change in ammonia data from the C columns provides the physical/chemical TN removal for each BAM type via physical filtration and sorption. This is illustrated in Figure 32, presented in formula format in Equation (8) and Equation (9), and calculated in Table 33. Additionally, the amount of TN removal due to biological process can also be calculated, see Equation (10) and Table 34. For every BAM type analyzed, physical/chemical processes dominated TN removal during the 22-minute EBCT and biological processes dominate during the 220-minute EBCT (see Table 34). This was likely due to the increased residence time, thus allowing for more biological nitrogen removal to occur.

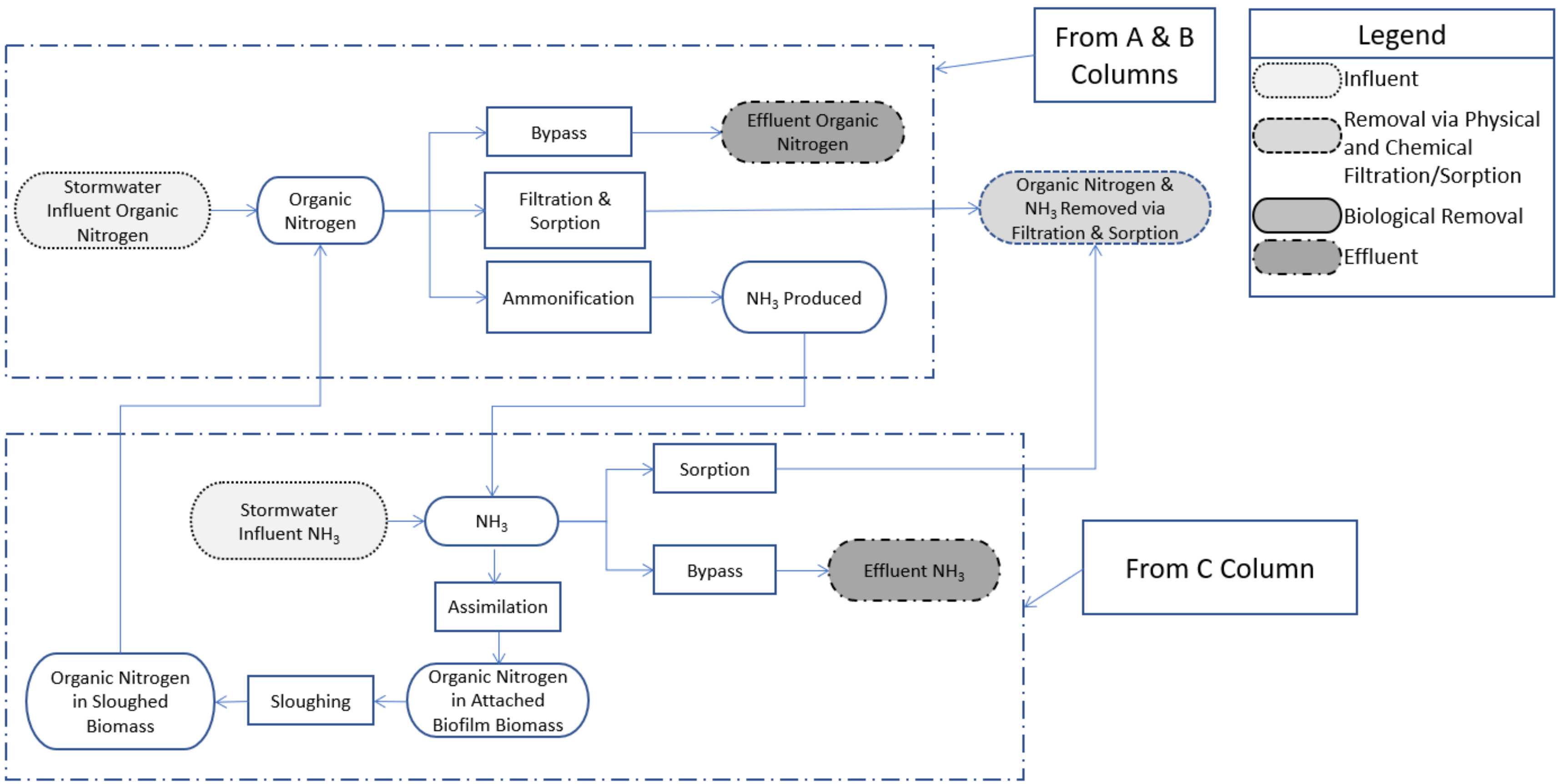

Figure 32: Development of Equation (8) from Columns A & B Nitrogen Cycle and Column C Nitrogen Cycle

$$\Delta\, TN\ due\ to\ Physical/Chemical\ processes = \Delta\, Organic\ Nitrogen_{A\ \&\ B\ Columns} + \Delta\, NH_{3_{C\ Column}} \quad (8)$$

Note:
Δ = Effluent – Influent, thus a positive Δ indicates an increase and a negative Δ indicates a decrease.

$$TN\ Removal\ due\ to\ Physical/Chemical\ processes = -1 * (\Delta\, TN\ due\ to\ Physical/Chemical\ processes) \quad (9)$$

Note:
Δ = Effluent – Influent, thus a positive Δ indicates an increase and a negative Δ indicates a decrease.

Table 33: Determining TN Removal due to Physical/Chemical Filtration & Sorption

EBCT (minutes)	**BAM #**	**Columns A & B Δ Organic Nitrogen (mg/L as N)**	**Column C ΔNH_3 (mg/L as N)**	**ΔTN due to Physical/Chemical processes (mg/L as N)**	**TN Removal due to Physical/Chemical processes (mg/L as N)**
22	1	-0.138	-0.054	-0.192	0.192
	2	-0.145	0.022	-0.123	0.123
	3	-0.178	0.004	-0.174	0.174
220	1	-0.027	-0.008	-0.035	0.035
	2	-0.101	-0.028	-0.129	0.129
	3	-0.065	-0.073	-0.138	0.138

Note:
Δ = Effluent – Influent, thus a positive Δ indicates an increase and a negative Δ indicates a decrease.

$$TN\ Removal\ due\ to\ Biological\ processes = TN\ Removal_{A\ \&\ B\ Columns} - TN\ Removal\ due\ to\ Physical/Chemical\ processes \quad (10)$$

Table 34: TN Removal due to Physical/Chemical Filtration & Sorption vs Biological Processes

EBCT (minutes)	BAM #	TN Removal (mg/L as N)	TN Removal due to Physical/Chemical processes (mg/L as N)	TN Removal due to Biological processes (mg/L as N)	% of TN Removal due to Physical/Chemical Filtration & Sorption	% of TN Removal due to Biological Processes
22	1	0.349	0.192	0.157	55%	45%
	2	0.210	0.123	0.087	59%	41%
	3	0.294	0.174	0.120	59%	41%
220	1	0.801	0.035	0.766	4%	96%
	2	0.300	0.129	0.171	43%	57%
	3	0.551	0.138	0.413	25%	75%

TN removal due to physical/chemical filtration and sorption dramatically decreased for BAM #1, and to a lesser degree for BAM #3, when the EBCT was increased from 22-minutes to 220-minutes. However, TN removal increased dramatically for BAM #1 and to lesser degree for BAM #3 when the EBCT was increased from 22-minutes to 220-minutes. Generally, sorption and filtration increase in efficiency with increased contact time and decreased velocity, however this did not occur for BAM #1 and BAM #3 [122, 123]. An explanation is that with the increased EBCT there was also an increase in denitrification. With the increase in TN removal via denitrification there may also be an increase in the sloughing of biofilm, which would contain organic nitrogen. Sloughing has been documented to occur in denitrifying biofilms due to the formation of nitrogen bubbles at the base of biofilms which dislodge the biofilm from the BAM particles as well as due to endogenous denitrification cannibalizing the biofilm at its base and causing it to break free [113-115, 117]. Note in Table 33 the decrease in organic nitrogen removal for all BAM types as the EBCT is increased from 22-minutes to 220-minutes, despite TN removal increasing with EBCT for all BAM types analyzed as shown in Table 34.

Can Chemoheterotrophic Denitrification Utilizing Organic Carbon Substrate Account for the Biological Removal of Total Nitrogen?

Stormwater is known for having low biodegradable organic carbon content (i.e. organic substrate), which presents issues for chemoheterotrophic denitrification utilizing organic substrate [15, 18]. Organic substrate is consumed by both heterotrophic bacteria that are not involved with the nitrogen cycle and heterotrophic bacteria involved in chemoheterotrophic denitrification [38]. Additionally, the lowest effluent DO concentration observed for all the columns was 0.4 mg/L which means the bulk water was under aerobic conditions throughout the columns [38]. Since the bulk water was aerobic throughout the column, heterotrophic bacteria located on the exterior surface of the biofilm consumed substrate aerobically, further reducing the available substrate for chemoheterotrophic denitrification in the interior, anoxic zone of the biofilm. If there is little to no substrate available there are two main alternative pathways for denitrification that may be involved, endogenous denitrification and Anammox [38, 42]. By analyzing the decrease in organic carbon in the columns it is possible to determine if more nitrogen is being removed than can be accounted for by chemoheterotrophic denitrifying bacteria utilizing organic substrate.

The influents and effluents of the BAM columns were analyzed for Total Organic Carbon (TOC). The measured decrease in TOC is referred to as TOC demand (TOCD). TOC was utilized, in lieu of biodegradable organic carbon, in nitrogen balances to determine if there was adequate substrate consumption for chemoheterotrophic denitrification utilizing organic substrate. Two limitations in using TOC are that TOC encompasses all types of organic carbon, not all of which are biodegradable, and that some TOCD may be due to physical/chemical filtration and sorption since organic carbon is known to sorb well and some of the TOC may be in particulate form [61, 124-126]. Thus, TOCD is an overestimation of the utilization of influent supplied biodegradable organic carbon (i.e. organic substrate) from the influent. TOC was assumed to be in the form of the chemical formula $C_{10}H_{19}O_3N$, which is commonly used to represent biodegradable organic matter in wastewater [38]. The median TOCD values for the various BAM types both EBCTs are presented in Table 35 and Box and Whisker plots of the measured TOCD values are presented in Figure 33 and Figure 34. Figure 34 is the same as Figure 33, except it is restricted to the range of -1.00 to 1.00 mg/L as C. Note that the TOCD is very small and sometimes slightly negative. The slightly negative values may be due to either sloughing of biofilm or error in the analytical measurement due to the small difference between the influent and effluent. The outliers in Figure 33 are all negative and large and can be attributed to sloughing of biofilm during that particular simulated storm event. The small TOCD values also indicate that the TOC is likely mostly non-biodegradable. Additionally, it would be expected that the TOCD would increase with an increase in EBCT, especially since the bulk water is under aerobic conditions. As presented in Table 35, the median TOCD only increases with increased EBCT for BAM #1, the other two types have a reduced TOCD. This further indicates that the TOCD is likely mostly non-biodegradable.

Table 35: Median TOCD

EBCT (minutes)	**BAM #**	**Influent TOC (mg/L as C)**	**TOCD (mg/L as C)**
22	1	7.62	0.05
	2	7.58	0.16
	3	7.58	0.17
220	1	8.00	0.10
	2	8.00	0.13
	3	8.00	0.03

Note:
TOCD = Influent TOC – Effluent TOC

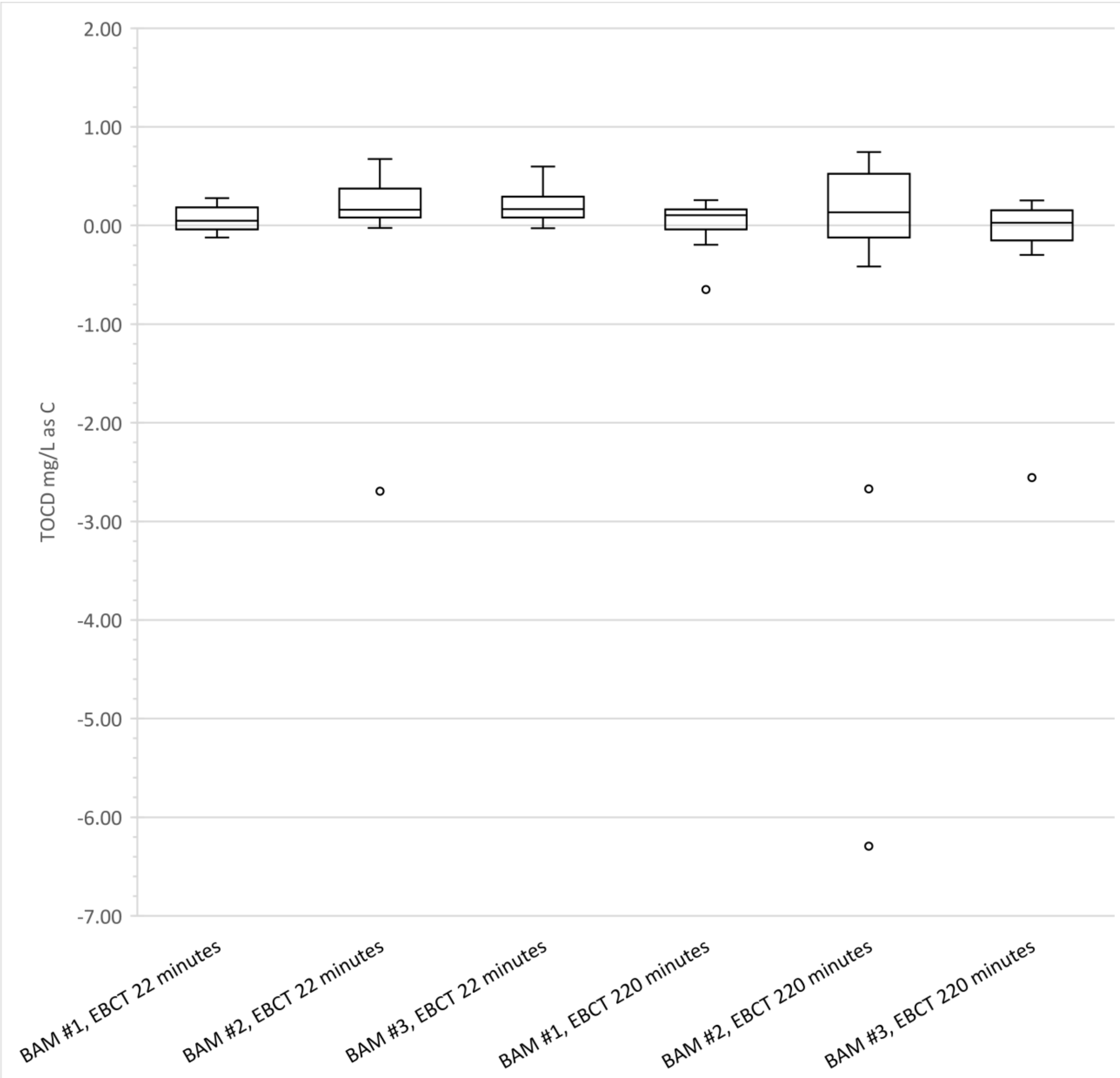

Figure 33: TOCD Values (entire range)

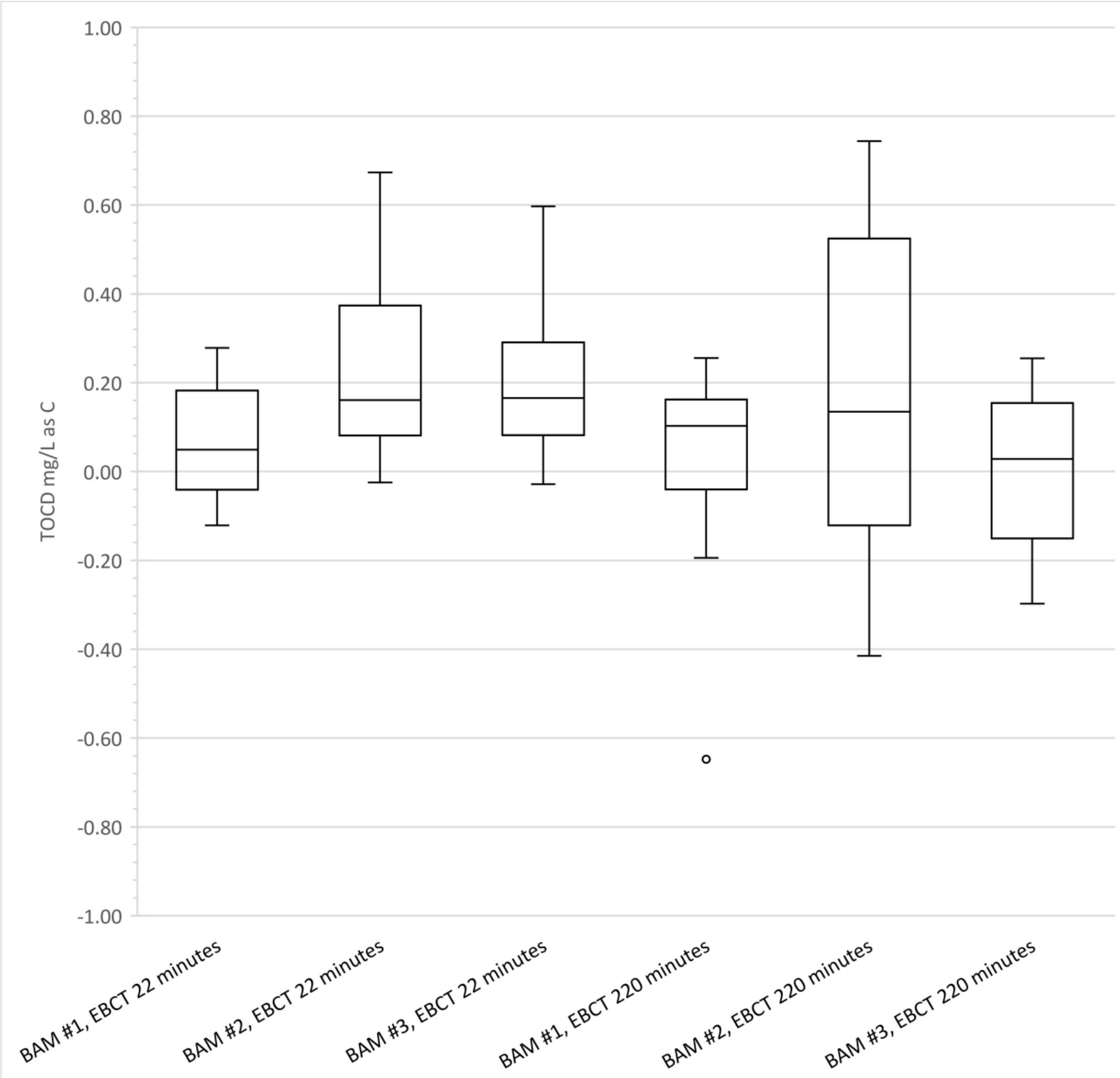

Figure 34: TOCD Values (only showing between -1.00 and 1.00 mg/L as C)

There were several key calculations and assumptions utilized in the mass balance. The amount of organic nitrogen and ammonia removed via chemical/physical process was determined utilizing Equation (9). The quantity of Influent TN, i.e. influent ammonia and organic nitrogen transformed to ammonia via ammonification, that was nitrified was calculated with Equation (11). The theoretical nitrogenous oxygen demand of the nitrified TN ($OD_{nitrification}$) was based on the complete nitrification reaction presented in Equation (4) and was calculated using Equation (12). The remaining oxygen consumption is attributed to TOC consumption by aerobic heterotrophic bacteria (OD_{TOC}) as shown in Equation (13). The OD_{TOC} is expressed in terms of aerobic chemoheterotrophic TOC demand ($TOCD_{aerobic}$) in Equation (15), based on the reaction for the aerobic chemoheterotrophic consumption of organic matter for respiration presented in Equation (14) [38, 127]. Whatever TOCD that cannot be accounted for during $TOCD_{aerobic}$ is attributed to TOC demand due to chemoheterotrophic denitrification utilizing substrate ($TOCD_{denitrification}$) as shown in Equation (16). If $TOCD_{aerobic}$ is greater than TOCD this indicates that there is negligible remaining substrate available for chemoheterotrophic denitrification, thus $TOCD_{denitrification}$ is considered to be 0 mg/L as C; the remaining $TOCD_{aerobic}$ can be attributed to aerobic endogenous respiration. The removal of TN due to chemoheterotrophic denitrification utilizing organic substrate was obtained utilizing Equation (18), which is based on the reaction for chemoheterotrophic denitrification utilizing substrate as shown in Equation (17) [38]. Any remaining biological TN removal that was not accounted for by chemoheterotrophic denitrification utilizing substrate was designated as due to endogenous denitrification and/or Anammox as shown in Equation (19).

$$\begin{aligned} &Amount\ of\ TN\ nitrified \\ &\qquad = (\Delta NOx - \Delta TN) \\ &\qquad - TN\ Removal\ due\ to\ Physical/Chemical\ processes \end{aligned} \tag{11}$$

Where $\Delta NOx - \Delta TN$ is equal to the *combined decrease of both organic nitrogen and ammonia* (also known as decrease in Total Kjeldahl Nitrogen).

Note:
•Δ = Effluent – Influent, thus a positive Δ indicates an increase and a negative Δ indicates a decrease.
•See APPENDIX K for derivation of equation for *combined decrease of both organic nitrogen and ammonia*.

$$OD_{nitrification} = (Amount\ of\ TN\ nitrified\ as\ mg\ of\ N) * \frac{2 * (15.9994 * 2)\ mg\ O_2}{14.0067\ mg\ N} \quad (12)$$

based on balanced nitrification reaction shown in Equation (4)

$$OD_{TOC} = (Measured\ DO\ consumption) - OD_{nitrification} \quad (13)$$

$$2C_{10}H_{19}O_3N + 25O_2 \rightarrow 14H_2O + 18CO_2 + 2NH_4^+ + 2HCO_3^- \quad (14)$$

$$TOCD_{aerobic} = (OD_{TOC}) * \frac{1\ mmol\ O_2}{(15.9994 * 2)\ mg\ O_2} * \frac{2\ mmol\ C_{10}H_{19}O_3N}{25\ mmol\ O_2} * \frac{10\ mmol\ C}{1\ mmol\ C_{10}H_{19}O_3N} * \frac{12.011\ mg\ C}{1\ mmol\ C} \quad (15)$$

$$TOCD_{denitrification} = TOCD - TOCD_{aerobic} \quad (16)$$

$$C_{10}H_{19}O_3N + 10NO_3^- \rightarrow 5N_2 + 10CO_2 + 3H_2O + NH_3 + 10OH^- \quad (17)$$

$$TN\ removal\ via\ chemoheterotrophic\ denitrification\ utilizing\ substrate$$

$$= \left(TOCD_{denitrification} \frac{mg}{L} as\ C\right) * \frac{10\ mmol\ NO_3^-}{1\ mmol\ C_{10}H_{19}O_3N} * \frac{1\ mmol\ C_{10}H_{19}O_3N}{10\ mmol\ C} * \frac{1\ mmol\ N}{1\ mmol\ NO_3^-} * \frac{1\ mmol\ C}{12.011\ mg\ C} * \frac{14.0067\ mg\ N}{1\ mmol\ N} \quad (18)$$

$$TN\ removal\ via\ Endogenous\ Denitrification\ and/or\ Anammox = (Total\ Biological\ TN\ Removal) - (\ TN\ removal\ via\ chemoheterotrophic\ denitrification\ utilizing\ substrate) \quad (19)$$

Note:
Removal = Influent – Effluent

Assumptions were required in the nitrogen mass balance that resulted in a favoring of the conclusion of biological TN removal via chemoheterotrophic denitrification utilizing substrate. However, if the mass balance shows that chemoheterotrophic denitrification via substrate is unable to account for some or all of the biological TN removal then it strengthens the case for Anammox and/or endogenous denitrification.

It is assumed that the TOCD is equivalent to biological organic substrate utilization in the mass balance, which, as stated previously on pages 108 and 109, is likely an overestimate. The mass balance will favor the conclusion of denitrification via chemoheterotrophic denitrification utilizing organic substrate due to this assumption regarding TOCD. However, if the mass balance shows that there is inadequate TOCD remaining after $TOCD_{aerobic}$ to account for some or all of the denitrification by chemoheterotrophic denitrification utilizing organic substrate ($TOCD_{denitrification}$) it makes a stronger, more conservative case for Anammox and/or endogenous denitrification accounting for a portion of the biological TN removal, see Equation (16).

Furthermore, in the mass balance it was assumed that all biological ammonia utilization was due to AOB, not Anammox. It was also assumed that nitrified ammonia proceeded all the way to nitrate, instead of stopping at nitrite, as shown in Equation (4). These assumptions caused an overestimation of the $OD_{nitrification}$ and thus underestimate the consumption of the $TOCD_{aerobic}$, see Equation (12) through Equation (15). The resulting underestimation of $TOCD_{aerobic}$ meant an overestimation of denitrification of NOx due to chemoheterotrophic denitrification utilizing organic substrate, see Equation (16) through Equation(18). An overestimation of chemoheterotrophic denitrification utilizing organic substrate leads to an underestimation of TN removal via endogenous denitrification and/or Anammox, as shown in Equation (19). Based on these assumptions the mass balance favors biological nitrogen removal via chemoheterotrophic denitrification utilizing organic substrate over Anammox and/or endogenous denitrification.

The inputs for the nitrogen balance laid out in Equation (11) through Equation (19) are presented in Table 36, the outputs of the nitrogen balance are presented in Table 37. After the aerobic consumption of TOCD is considered ($TOCD_{aerobic}$) there is no TOCD remaining for chemoheterotrophic denitrification utilizing organic substrate ($TOCD_{denitrification}$). Thus, on average, no nitrogen removal occurred via chemoheterotrophic denitrification utilizing substrate for all BAM types during both the 22-minute and 220-minute EBCT. As a result, biological TN removal was due to Anammox and/or endogenous denitrification.

Table 36: Inputs for Chemoheterotrophic Denitrification utilizing Organic Substrate vs Anammox and/or Endogenous Denitrification Mass Balance

EBCT (minutes)	BAM #	ΔTN (mg/L as N)	ΔNOx (mg/L as N)	ΔNH_3 (mg/L as N)	Measured DO consumption (mg/L as O_2)	TOCD (mg/L as C)	TN Removal due to Physical/Chemical processes (mg/L as N)	TN Removal due to Biological processes (mg/L as N)
22	1	-0.349	0.150	-0.361	2.90	0.05	0.192	0.157
	2	-0.210	0.242	-0.275	1.90	0.16	0.123	0.087
	3	-0.294	0.280	-0.373	2.85	0.17	0.174	0.120
220	1	-0.801	-0.220	-0.513	4.00	0.10	0.035	0.766
	2	-0.300	0.384	-0.554	4.30	0.13	0.129	0.171
	3	-0.551	0.017	-0.489	4.40	0.03	0.138	0.413

Note:
•Δ = Effluent – Influent, thus a positive Δ indicates an increase and a negative Δ indicates a decrease.
•Removal = Influent – Effluent

Table 37: Outputs for Chemoheterotrophic Denitrification utilizing Substrate vs Anammox and/or Endogenous Denitrification Mass Balance

EBCT (minutes)	BAM #	Amount of TN nitrified (mg/L as N)	$OD_{nitrification}$ (mg/L as O_2)	OD_{TOC} (mg/L as O_2)	$TOCD_{aerobic}$ (mg/L as C)	$TOCD_{denitrification}$ (mg/L as C)	TN Removal via Chemo-heterotrophic Denitrification utilizing Substrate (mg/L as N)	TN Removal via Endogenous Denitrification and/or Anammox (mg/L as N)
22	1	0.307	1.400	2.594	0.779	0.000	0.000	0.157
	2	0.329	1.503	1.571	0.472	0.000	0.000	0.087
	3	0.400	1.828	2.450	0.736	0.000	0.000	0.120
220	1	0.546	2.495	3.454	1.037	0.000	0.000	0.766
	2	0.555	2.536	3.745	1.125	0.000	0.000	0.171
	3	0.430	1.965	3.970	1.192	0.000	0.000	0.413

Note:
•Δ = Effluent – Influent, thus a positive Δ indicates an increase and a negative Δ indicates a decrease.
•Removal = Influent – Effluent

Biological Nitrogen Removal via Endogenous Denitrification & Anammox

Now that it has been established that chemoheterotrophic denitrification utilizing organic substrate was not a pathway for denitrification in the upflow BAM columns, there are two possible options; endogenous denitrification and Anammox. Endogenous denitrification is well documented in suspended and attached growth systems whereas Anammox is considered a more novel pathway and was discovered in the mid-1990s [38, 128]. Anammox, however, has been demonstrated to be an effective method of denitrification in attached growth systems [38, 42, 129].

Presence of Anammox

To determine if Anammox was present in the upflow BAM columns PCR analysis was conducted on BAM samples taken from both the top and bottom sampling ports of the A columns of each of the three BAM types (see Figure 17). The functional gene sequence for Anammox is 665 base pairs in length (see Table 27). Gel electrophoresis was used to analyze the Anammox PCR products.

Gel electrophoresis is a technique to separate DNA fragments by base pair length; shorter fragments will migrate more quickly through the gel and longer fragments will migrate more slowly [130]. In the gel image in Figure 35, the DNA fragments (PCR products) were loaded into the wells located at the top of the gel and they migrated towards the bottom during electrophoresis, thus separating the DNA fragments by size with the longer fragments advancing more slowly from the top and shorter fragments advancing more rapidly towards the bottom. This is seen in the DNA ladder that was included in the gel on both the far left and far right. In addition to the DNA ladders and Anammox PCR products from extracted BAM DNA samples, the gel in Figure 35 also contains a negative and positive control. The negative control is used to rule out any contamination of the PCR reaction mix. The positive control is used to verify that a successful PCR run for the target was possible as well as provide a visual marker for where the PCR products from the extracted BAM samples should be if they contain the target gene. Note that the Anammox positive control has a bright band between the 600 base pair (bp) and 700 bp markers on the ladder, which agrees with the known length of 621 bp of the Anammox functional gene sequence [116].

As shown in the image of the 2% agarose ethidium gel (see Figure 35), the Anammox functional gene sequence was found in both the top and bottom sampling ports of all three types of BAM utilized in this study. Both the influent and effluent water of each of the A & B columns had a DO of over 0.2 mg/L indicating an aerobic environment in the bulk water, see Table 30 [38]. The fact that Anammox was found to be present at both the top and bottom sampling ports, despite the surrounding bulk water being aerobic, indicates that the Anammox did exist in the depth of a layered biofilm where the conditions are anoxic as proposed in Figure 2.

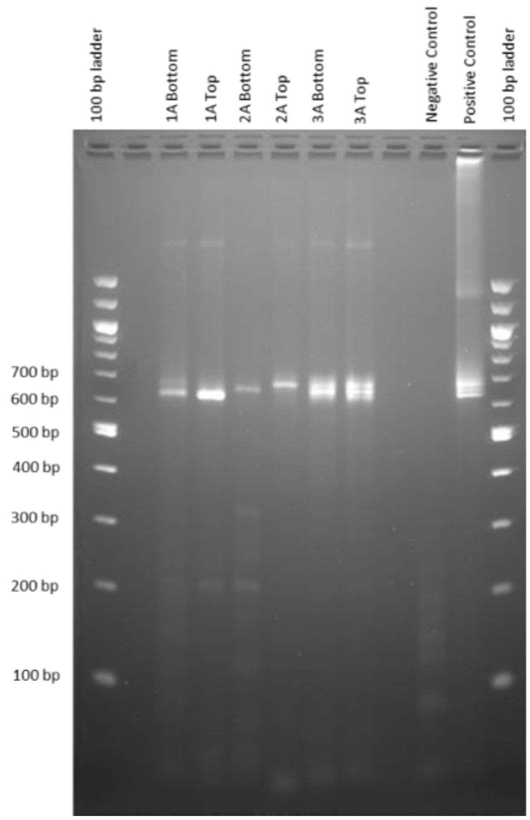

Figure 35: 2% Agarose Ethidium Bromide Gel showing Anammox PCR Products

Endogenous Denitrification

Endogenous denitrification occurs when there is inadequate organic substrate and as a result cells are broken down for their organic carbon via endogenous respiration [38, 42]. Thus, assuming excess NOx, the endogenous denitrification rate in the BAM columns was limited by the rate at which endogenous respiration can break down biomass to obtain organic carbon [38]. Excess NOx concentration is defined as 0.1 mg/L as N and greater when chemoheterotrophic denitrification is considered [38].

As mentioned earlier, the nitrification inhibitor prevented formation of nitrite and nitrate from ammonia. Due to lack of nitrite formation and negligible amounts of nitrite in the influent, removal of influent supplied NOx in the C columns was assumed to be due to endogenous denitrification rather than Anammox. Thus, the NOx removal in the C columns was representative of endogenous denitrification in the A & B columns only if both the influent and effluent NOx concentrations in the columns were above 0.1 mg/L as N [38]. As presented in Table 38, this was the case for all BAM types during the 22-minute EBCT, but only true for BAM #2 during the 220 minute EBCT. The range of endogenous denitrification values for each BAM type during both EBCTs that were controlled by the endogenous respiration rate are presented in Figure 36 and the average values are presented in Table 39.

Table 38: C Column Average Effluent NOx Concentrations

EBCT (minutes)	BAM #	Influent NOx (mg/L as N)	Effluent NOx (mg/L as N)
22	1	0.230	0.182
	2	0.230	0.209
	3	0.230	0.180
220	1	0.244	0.021
	2	0.244	0.161
	3	0.244	0.033

Table 39: Average Endogenous Denitrification Values

EBCT (minutes)	BAM #	Removal of NOx via Endogenous Denitrification (mg/L as N)
22	1	0.042
	2	0.020
	3	0.040
220	1	*Unable to determine
	2	0.063
	3	*Unable to determine

Note:
•Removal = Influent – Effluent
•*Unable to determine removal via endogenous denitrification due to C columns having an effluent NOx concentration less than 0.1 mg/L as N; thus potentially limiting the endogenous denitrification rate due to NOx not being in excess [38].

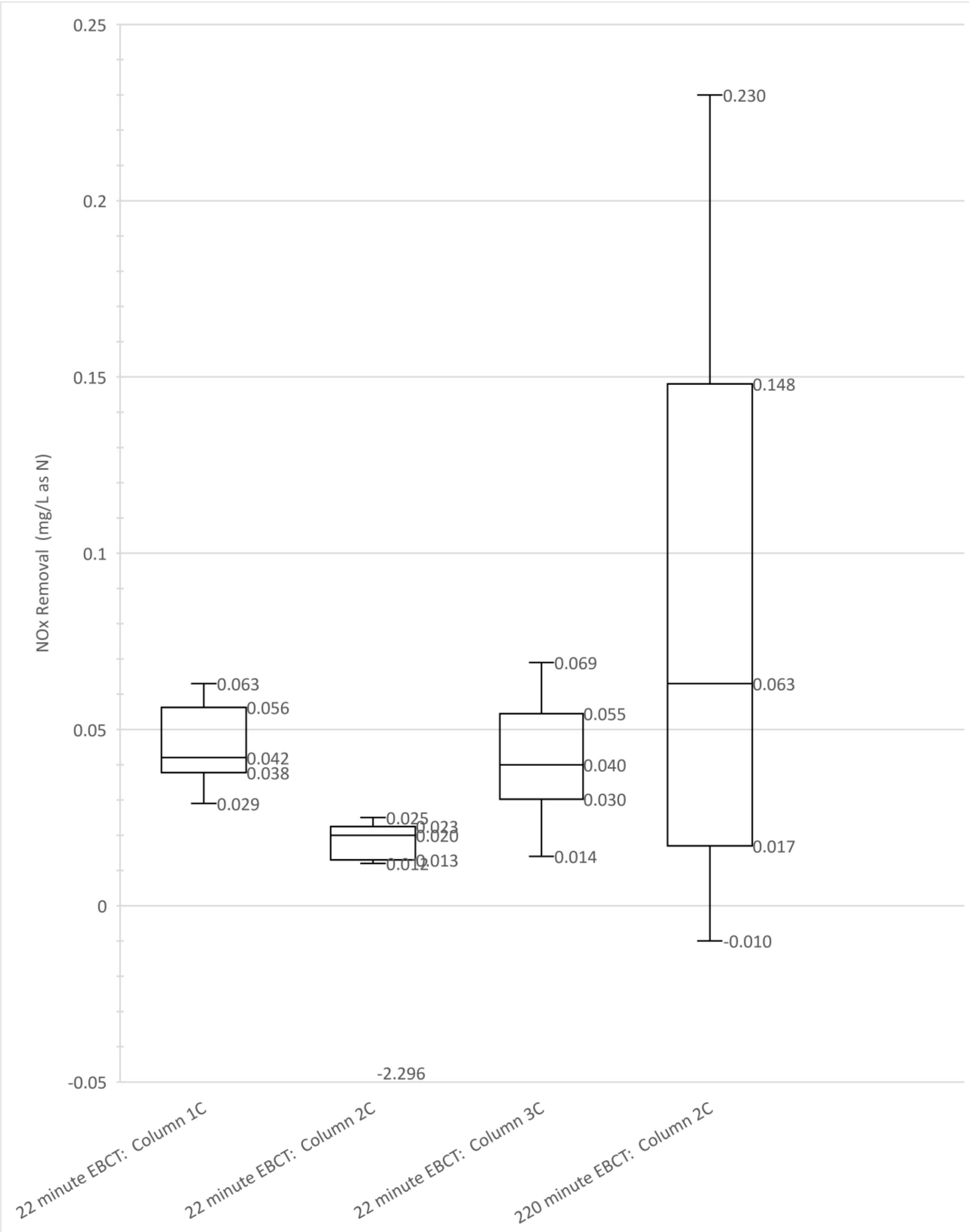

Figure 36: NOx Removal via Endogenous Denitrification

Denitrification via Anammox

It has been established that chemoheterotrophic denitrification utilizing substrate was not a pathway for denitrification in the upflow BAM columns, thus the biological removal of TN that cannot be accounted for by endogenous denitrification is attributed to chemoautotrophic denitrification by Anammox; this is illustrated in Equation (20) [38]. Recall that it has been established that Anammox was present in the three types of BAM analyzed and has been documented in literature to be a mechanism in fixed growth denitrification systems [38, 42, 45].

The average TN removals due to endogenous denitrification and Anammox are calculated using Equation (20) and presented in Table 40. Anammox was the dominant biological removal mechanism of TN for all BAM types during the 22-minute EBCT as well as for BAM #2 during the 220-minute EBCT. As discussed previously, the amount of TN removal via endogenous denitrification could not be established for BAM #1 and BAM #3 during the 220-minute EBCT. Since the TN removal due to Anammox is calculated using Equation (20), which depends on knowing the TN removal due to endogenous denitrification, the TN removal due to Anammox could also not be determined for BAM #1 and BAM #3 during the 220-minute EBCT. However, based on the high percentage of Anammox contribution with the BAM# 2 in the 220-minute EBCT, it can be inferred that Anammox might have also played a significant part in the biological removal of TN during the 220-minute EBCT for both BAM #1 and BAM #3. The finding that Anammox was responsible for more of the biological nitrogen removal in the upflow BAM filters than endogenous denitrification agrees with a study that focused on treating wastewater with low organic carbon, under bulk water aerobic conditions, with layered biofilms creating deeper anoxic zones in a moving-bed pilot plant [42].

$$Removal\ of\ TN\ via\ Anammox =$$
$$TN\ removal\ via\ Endogenous\ Denitrification\ and/or\ Anammox - \qquad (20)$$
$$Removal\ of\ TN\ via\ Endogenous\ Denitrification$$

Table 40: TN Removal due to Anammox and Endogenous Denitrification

EBCT (minutes)	BAM #	TN Removal via Endogenous Denitrification and/or Anammox (mg/L as N)	Removal of TN via Endogenous Denitrification (mg/L as N)	Removal of TN via Anammox (mg/L as N)	% of Biological TN Removal due to Endogenous Denitrification	% of Biological TN Removal due to Anammox
22	1	0.157	0.042	0.115	27%	73%
	2	0.087	0.020	0.067	23%	77%
	3	0.120	0.040	0.080	33%	67%
220	1	0.766	*Unable to determine			
	2	0.171	0.063	0.108	37%	63%
	3	0.413	*Unable to determine			

Note:
•*TN Removal due to Biological Processes* is equal to *TN removal via Endogenous Denitrification and/or Anammox* due to *Chemoheterotrophic Denitrification Utilizing Substrate* not accounting for any TN removal, see Table 36 and Table 37.
•*Unable to determine removal via endogenous denitrification, also removal via Anammox, due to C columns having an effluent NOx concentration less than 0.1 mg/L as N; thus potentially limiting the endogenous denitrification rate due to NOx not being in excess [38].

Limitations of Allocation of Total Nitrogen Removal Due to Endogenous Denitrification & Anammox

It was assumed in the analysis above that all NOx consumption in the C columns was due to endogenous chemoheterotrophic denitrification. The purpose was to segment the contributions to TN removal between endogenous denitrification and Anammox, with an emphasis on determining if Anammox was a significant part of the TN removal in the BAM columns. There are however potential alternate pathways for the decrease of NOx concentrations in the C columns; thus, the assumption that all NOx consumption in the C columns was due to endogenous chemoheterotrophic denitrification may have led to an overestimate of TN removal due to endogenous chemoheterotrophic denitrification and an underestimate in TN removal due to Anammox [32, 131-133].

Dissimilatory nitrate reduction to ammonium (DNRA) is an obligate-anaerobic, chemoheterotrophic, 2-step process that reduces nitrate to nitrite and then reduces nitrite to ammonium [132, 133]. There are no known bacteria that are capable of both chemoheterotrophic denitrification and DNRA [133]. DNRA bacteria compete with chemoheterotrophic denitrifying bacteria for nitrate [134]. Furthermore, DNRA tends to dominate over chemoheterotrophic denitrification when organic carbon (electron donor) is in excess and NOx (electron acceptor) is limiting [133-135]. Nitrate that has been reduced all the way to ammonia may potentially be removed via Anammox [131, 132]. In addition to reducing nitrate all the way to ammonia, literature indicates that the DNRA process may also supply the nitrite for Anammox [131, 132]. The combination of DNRA and Anammox may even have an energetic advantage over chemoheterotrophic denitrification despite chemoheterotrophic denitrification being more thermodynamically favorable than DNRA [131]. For the upflow BAM columns in this research, whether DNRA is reducing nitrate all the way to ammonia, or if it is reducing nitrate to nitrite for use by Anammox, it would cause an over estimation in TN removal by endogenous denitrification since the TN removal attributed to endogenous denitrification is based on the decrease in NOx in the C Columns. An overestimation of TN removal due to endogenous denitrification would result in an underestimation of denitrification via Anammox.

DNRA has been found in BAM in a previous study so there is precedent for its potential presence and impact; however, that research was on BAM applied on the bottom of a vegetated stormwater infiltration basin where settled organic carbon and vegetation root biomass may have provided biologically available organic carbon [32]. Literature states that DNRA tends to dominate over chemoheterotrophic denitrification when organic carbon is in excess compared to NOx [133-135]. The BAM upflow columns in this study had the anoxic zones of the biofilm operating in an endogenous state in regards to chemoheterotrophic respiration due to all TOC consumption being accounted for aerobically, thus organic carbon was not readily available (see Table 37). Furthermore, as shown in Table 38, all BAM types during the 22-minute EBCT and BAM #2 during the 220-minute EBCT had C column NOx concentrations above 0.1 mg/L as N NOx, which is considered excess for chemoheterotrophic denitrification [38]. Thus, the impact of DNRA on the TN removal due to endogenous denitrification during the 22-minute EBCTs is assumed to be negligible. DNRA may have been a factor during the 220-minute EBCTs due to NOx potentially not always being in excess with respect to organic carbon (see Table 38).

Conclusions

The removal of nitrogen from stormwater is a significant design consideration for stormwater engineers, however the plug flow nature of stormwater treatment BMPs and the typically low concentration of biologically available organic carbon, when compared to wastewater, can present denitrification issues. This study demonstrated that upflow BAM treatment systems are a viable solution for the removal of nitrogen that is in a dominantly dissolved or non-settable solid form. The TN removal efficiencies and average changes in concentration for TN, organic nitrogen, ammonia, and NOx for all three BAM types are presented in Table 41. BAM #1 achieved the highest TN removal efficiency for both the 22-

minute and 220-minute EBCTs, see Table 41. Furthermore, it was demonstrated that not only was Anammox present in the biofilm of all three varieties of BAM analyzed, but also that it was a major contributor to nitrogen removal. The ratios of the various removal mechanisms are presented in Table 42.

Table 41: Average Changes in Nitrogen

EBCT (minutes)	BAM #	TN Removal Efficiency	Δ TN (mg/L as N)	Δ Organic Nitrogen (mg/L as N)	Δ NH_3 (mg/L as N)	Δ NOx (mg/L as N)
22	1	23%	-0.349	-0.138	-0.361	0.150
	2	14%	-0.210	-0.145	-0.28	0.242
	3	19%	-0.294	-0.178	-0.373	0.280
220	1	50%	-0.801	-0.027	-0.513	-0.220
	2	19%	-0.300	-0.101	-0.554	0.384
	3	37%	-0.551	-0.065	-0.489	0.017

Note:
Δ = Effluent – Influent, thus a positive Δ indicates an increase and a negative Δ indicates a decrease.

Table 42: Ratios of TN Removal Mechanisms

EBCT (minutes)	BAM #	TN Removal (mg/L as N)	% of TN Removal due to Physical/Chemical Filtration & Sorption	% of TN Removal due to Chemoheterotrophic Denitrification utilizing Substrate	% of TN Removal due to Endogenous Denitrification	% of TN Removal due to Anammox
22	1	0.349	55%	0%	12%	33%
	2	0.210	59%	0%	10%	32%
	3	0.294	59%	0%	14%	27%
220	1	0.801	4%	0%	*Unable to determine individually, net is 96%	
	2	0.300	43%	0%	21%	36%
	3	0.551	25%	0%	*Unable to determine individually, net is75%	

Note:
*Unable to determine removal via endogenous denitrification, also removal via Anammox, due to C columns having an effluent NOx concentration less than 0.1 mg/L as N; thus potentially limiting the endogenous denitrification rate due to NOx not being in excess [38].

As expected, TN removal increased for all BAM types when the EBCT was increased from 22-minutes to 220-minutes, see Table 41. Of interesting note however is that for every BAM type analyzed, physical/chemical filtration & sorption processes dominated TN removal during the shorter 22-minute EBCT but biological removal dominated during the 220-minute EBCT, see Table 42 and Table 34. This is likely due to the increased residence time allowing for more biological nitrogen transformations and removal to occur.

In addition to BAM# 1 achieving the highest TN removal efficiency, it also possessed the highest permeability constant, therefore it can achieve high flow rates with minimal head loss compared to the other BAM types analyzed in this study (see Table 22). Having both the highest TN removal performance and highest permeability constant makes BAM #1 an attractive media option for biosorption media based BMPs. Furthermore, BAM #1 had the smallest net increase in NOx for the 22-minute EBCT and the only net decrease of NOx during the 220-minute EBCT (see Table 41). The net reduction of NOx during the 220-minute EBCT for BAM #1 indicates denitrification was occurring at a rate greater than nitrification. This is of particular interest in stormwater because NOx and ammonia are the forms of nitrogen that are readily biologically available to plants, algae, and bacteria [61]. The high nitrogen removal performance of BAM# 1 compared to the other BAM types analyzed may have been due to its high content of expanded clay and tire crumb, thus providing significant sorption material and surface area for biofilm growth.

The finding that Anammox was a significant contributor to the biological nitrogen removal in the upflow BAM columns is noteworthy (see Table 42 and Table 40). This finding has real world design applications because stormwater typically has a low biologically available organic carbon content and, as demonstrated in this research, chemoheterotrophic denitrification utilizing organic substrate may not be biologically possible. In other studies, researchers have analyzed BMPs utilizing a media mixture that incorporated a biologically available organic carbon source such as wood, straw, and maize cobs, thus enabling chemoheterotrophic denitrification utilizing BAM supplied organic carbon [136, 137]. However, organic carbon sources that are mixed into a media have the disadvantage of being consumed over time; limiting the denitrification life span of the media. Using a BAM mix that incorporates a supplemental organic carbon source would be necessary if the nitrogen in the influent was dominantly in the form of nitrate, since Anammox cannot utilize nitrate. However, if organic nitrogen, ammonia, or ammonia and nitrite are the nitrogen species present in the influent and the organic carbon concentration is low, then an upflow BMP utilizing BAM #1, which contains no supplemental organic carbon, may be a feasible choice since it relies on nitrification, Anammox, and endogenous denitrification for biological nitrogen removal.

CHAPTER 6: CONCLUSIONS & RECOMMENDATIONS

Introduction

The treatment of stormwater to meet nutrient total maximum daily load requirements or removal regulations can be challenging. In ultra-urban areas where space limitations make traditional stormwater BMPs, such as stormwater ponds, impractical, upflow filters utilizing BAM that can be placed underground offer a small footprint alternative. Additionally, BAM upflow filters can be installed at the discharge point of traditional stormwater ponds to provide further treatment. Nitrogen and phosphorus are the limiting macro nutrients in aquatic systems and thus are a major focus in stormwater treatment for the purpose of improving ecosystem health [10]. Furthermore, bacterial pathogens in stormwater are a concern as elevated levels of pathogens can pollute the receiving water body, causing adverse health impacts on humans and wildlife that interact with the water body [1, 2].

This research simulated stormwater that had already been treated for solids removal; thus, most of the nutrients and solids in the simulated stormwater influent were assumed to be as non-settable suspended solids or dissolved solids. The overall goals of this research were to evaluate and compare the nutrient and bacterial pathogen water quality improvement performance of upflow filter systems using three different types of BAM at EBCTs of 22-minutes and 220-minutes. BAM removes pollutants through a combination of sorption, physical filtration, and biological processes. The shorter EBCT represented an ultra-urban stormwater system with no attenuation prior to the upflow filter and the longer EBCT represented an attenuated stormwater style treatment system or a continuous low flow baseflow with no attenuation. An example of an attenuated upflow filter stormwater treatment system would be an underground vault that stores the water during the storm event and allows for a controlled discharge through the upflow filter, thus enabling a longer EBCT. The pollutants of interest were nitrogen, phosphorus, total coliform, E. coli, and HPC. Additionally, it was sought to determine the pathways by which nitrogen was being removed from the system, with special interest in denitrification since stormwater typically has low organic carbon content. A detailed nitrogen balance combined with PCR analysis for Anammox was utilized to investigate denitrification pathways.

Nutrients

BAM #1 had the greatest decrease in total nitrogen, total phosphorus, and SRP for both the 22-minute and 220-minute EBCT making it an excellent choice for nutrient decrease in upflow filter BMPs. The total nitrogen removal efficiencies of BAM #1 were 23% and 50% respectively for the 22-minute and 220-minute EBCTs. The total phosphorus removal efficiencies of BAM #1 were 51% and 44% respectively for the 22-minute and 220-minute EBCTs. Additionally, BAM #1 had the highest permeability constant of all the BAM types tested, 475.25 in/hr, meaning it requires far less driving head.

A noteworthy finding was that Anammox was the dominant form of biological TN removal based on the nitrogen mass balances. The presence of Anammox was further confirmed in all BAM types tested using PCR analysis. Nitrogen removal via chemoheterotrophic denitrification utilizing organic substrate was found to be negligible. The remainder of the biological nitrogen removal was attributed to endogenous denitrification. The finding that Anammox is responsible for most of the biological removal of nitrogen has design impacts. For example, BAM #1 would likely work well in treating water that has elevated ammonia since it can be nitrified to nitrite and then Anammox can reduce the nitrite with ammonia to nitrogen gas. However, BAM #1 will likely not work well in removing nitrogen from an influent whose nitrogen in dominantly in the form of nitrate since Anammox is not capable of utilizing nitrate at a significant rate.

Bacterial Pathogens

All BAM types for both EBCTs removed total coliform with BAM #1 having the highest removal efficiency during both the 22-minute and 220-minute EBCTs, 76% and 96% respectively. However, during the 220-minute EBCT, all BAM types achieved average total coliform removals in excess of 93%. Additionally, it can be tentatively concluded that upflow BAM filters are capable of reducing E. coli concentrations, but it was not possible to determine a quantifiable comparison between the BAM varieties due to a small data set caused by the influent source water having E. coli concentrations right at or below the detection limit of 100 MPN per 100 mL.

HPC may be a parameter of concern for the stormwater BMP effluent if it is being used as influent for a membrane drinking water plant, such as reverse osmosis or nano filtration, due to biofouling of the membranes [3, 4]. Upflow BAM filters were shown not to be an acceptable method of HPC reduction. With the exception of BAM #3 during the 22-minute EBCT, all BAM types resulted in an increase in HPC during both the 22-minute and 220-minute EBCT, with a greater increase occurring during the longer 220-minute EBCT. The greater increase in HPC with the longer EBCT indicates a greater amount of biological activity during the 220-minute EBCT compared to the 22-minute EBCT. This indicates that a portion of sloughed biofilm is exiting the BAM upflow system in the effluent. The conclusion that a portion of sloughed biofilm was being discharged in the effluent of the BAM upflow filter system was also supported by the decrease in TSS removal with increased EBCT, and the decrease in organic nitrogen removal with increased EBCT. Additionally, SRP removal was greater than total phosphorus removal for all BAM types during the 220-minute EBCT, which further supports this conclusion. The discharge of sloughed biofilm in the effluent may explain why BAM #1, which had the greatest total coliform removal did not have the greatest TSS removal. Sloughed biomass in the effluent would be detected as TSS, thus the BAM upflow columns are both removing influent suspended solids and generating suspended solids, thus obscuring a total coliform removal and TSS removal relationship.

Future Work

BAM #1 performance results make it attractive for usage in upflow BMP design. As such, further research is needed to develop removal performance vs EBCT curves at various influent concentrations. Various EBCT values could be achieved from a single run by installing several sampling ports along the length of the columns. Of particular interest would be investigating removal performance of total nitrogen at various ammonia concentrations since ammonia is necessary for production of nitrite via nitrification and for subsequent removal of total nitrogen by reduction of nitrite into nitrogen gas via Anammox. Additionally, monitoring nitrite as opposed to NOx as a whole may lead to an improved mass balance for the contribution of Anammox. Analysis at a variety of temperatures would also be helpful for determining if this system works well in different climate regions.

APPENDIX A
PERMISSIONS

FDOT Master University Agreement

The Florida Department of Transportation (FDOT) was the funding agency for this research and a FDOT Final Report was prepared and submitted to the FDOT based on this research.

In Section 10 (Publication Provisions) of the FDOT Master University Agreement (#BDK78) it states, in summary, that material published in the FDOT Final Report may be published without further written permission from the FDOT.

The reference for the FDOT Final Report is: Wanielista, M., et al., Demonstration Bio Media for Ultra-urban Stormwater Treatment. 2014, FDOT.

Portions of the above-mentioned FDOT Final Report are incorporated into this dissertation.

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RESULTS OF SAMPLE ANALYSES CONDUCTED ON SAMPLES COLLECTED FOR THE "BAM" PROJECT -- UCF Project No. 16607051

DATE COLLECTED	SAMPLE DESCRIPTION	ALKALINITY (mg/l)	NO_x (µg/l)	NH_3 (µg/l)	TOTAL N (µg/l)	SRP (µg/l)	TOTAL P (µg/l)	TSS (mg/l)
5/1/13	Column 1 A	85.6	273	343	637	87	97	1.0
	Column 1 B	70.2	273	370	744	123	129	1.4
	Column 1 C	73.2	269	305	1,110	102	113	1.2
	Column 2 A	62.8	404	254	719	52	86	2.6
	Column 2 B	69.0	363	333	721	64	197	7.4
	Column 2 C	67.8	277	422	1,225	139	403	16.2
	Column 3 A	78.8	270	387	689	122	129	0.6
	Column 3 B	75.0	284	389	718	104	237	61.2
	Column 3 C	82.6	270	391	1,314	102	106	1.0
	Influent	73.4	331	319	696	206	221	1.8
6/6/13	Column 1 A	72.6	195	751	1,061	65	77	3.4
	Column 1 B	71.4	225	725	1,276	119	122	3.8
	Column 1 C	71.6	217	818	2,263	113	115	1.2
	Column 2 A	65.4	300	738	1,143	75	78	2.4
	Column 2 B	64.6	268	794	1,226	84	165	3.8
	Column 2 C	67.8	229	918	1,783	155	674	81.4
	Column 3 A	76.2	229	838	1,167	100	103	1.2
	Column 3 B	75.8	226	833	1,149	108	109	1.8
	Column 3 C	77.8	223	898	2,025	87	98	1.7
	Influent 1,2	70.2	220	841	1,549	236	241	3.8
	Influent 3	68.2	233	875	1,611	224	232	x
6/13/13	Column 1 A	73.2	198	529	1,249	62	71	1.4
	Column 1 B	74.0	204	475	1,025	62	82	2.2
	Column 1 C	70.8	190	611	2,016	80	98	2.4
	Column 2 A	66.8	369	533	1,067	85	90	1.0
	Column 2 B	62.5	309	604	1,213	114	183	6.2
	Column 2 C	60.2	225	797	1,802	99	784	34.4
	Column 3 A	81.2	250	652	1,102	106	123	1.0
	Column 3 B	74.4	256	354	938	113	124	1.0
	Column 3 C	83.0	196	433	1,454	95	105	3.2
	Influent 1,2	64.6	219	692	1,671	180	189	4.2
	Influent 3	x	220	717	1,554	x	x	x

Analytical results presented in this report have been reviewed for compliance with the ENVIRONMENTAL RESEARCH & DESIGN, INC. (ERD) Quality Systems Manual and have been determined to meet applicable method guidelines and standards referenced in the July 2003 National Environmental laboratory Accreditation Program (NELAP) Quality Manual unless otherwise noted. The Analytical Results within these report pages reflect the values obtained from tests performed on samples as received by the laboratory unless indicated differently.

Cassie Pelto
Cassie Pelto
Lab Director

NELAC No. E1031026

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DATE COLLECTED	SAMPLE DESCRIPTION	ALKALINITY (mg/l)	NO_x (µg/l)	NH_3 (µg/l)	TOTAL N (µg/l)	SRP (µg/l)	TOTAL P (µg/l)	TSS (mg/l)
6/20/13	Column 1 A	73.0	183	531	1,472	71	107	1.6
	Column 1 B	67.0	185	485	777	66	105	1.8
	Column 1 C	63.0	184	616	3,603	98	119	3.8
	Column 2 A	71.4	353	627	1,113	98	107	1.2
	Column 2 B	59.8	302	565	1,452	153	317	38.6
	Column 2 C	58.8	210	797	1,520	108	759	60.4
	Column 3 A	75.0	255	658	1,241	124	126	3.4
	Column 3 B	76.2	254	680	1,138	126	130	1.0
	Column 3 C	77.0	189	766	1,818	114	123	2.2
	Influent 1,2	74.4	216	690	1,323	204	211	2.4
	Influent 3	x	x	x	2,544	x	x	x
6/26/13	Column 1 A	96.4	24	228	843	20	106	1.0
	Column 1 B	82.8	99	199	900	30	137	4.2
	Column 1 C	98.6	5	312	3,799	32	122	2.2
	Column 2 A	73.0	336	329	1,488	78	99	0.8
	Column 2 B	76.6	689	256	1,289	96	126	0.6
	Column 2 C	70.4	238	685	1,038	72	108	1.2
	Column 3 A	106	73	172	874	136	178	0.6
	Column 3 B	107	76	218	796	131	177	2.0
	Column 3 C	112	15	366	3,550	126	165	1.2
	Influent I	72.4	238	620	1,386	173	191	1.6
	Influent II	x	x	x	3,594	x	x	x
7/2/13	Column 1 A	90.4	520	207	2,157	78	209	3.0
	Column 1 B	85.0	468	181	1,804	57	220	6.2
	Column 1 C	90.2	563	182	4,674	82	186	6.4
	Column 2 A	73.4	453	347	1,885	122	207	1.8
	Column 2 B	74.6	402	308	1,830	149	298	1.6
	Column 2 C	82.2	621	193	4,366	120	306	8.8
	Column 3 A	103	560	247	1,236	19	136	2.0
	Column 3 B	94.0	497	250	1,373	95	131	3.2
	Column 3 C	98.6	635	167	4,094	112	200	4.8
	Influent I	79.2	526	210	2,674	211	406	10.4
	Influent II	x	x	x	4,893	x	x	x
	Column 4 A	x	x	152	x	x	x	x
	Column 4 B	x	x	221	x	x	x	x
	Column 4 C	x	x	350	x	x	x	x
	Column 5 A	x	x	x	x	121	x	x
	Column 5 B	x	x	x	x	494	x	x
	Column 6 A	x	470	x	x	x	x	x

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RESULTS OF SAMPLE ANALYSES CONDUCTED ON SAMPLES COLLECTED FOR THE "BAM" PROJECT -- UCF Project No. 16607051

DATE COLLECTED	SAMPLE DESCRIPTION	ALKALINITY (mg/l)	NO_x (µg/l)	NH_3 (µg/l)	TOTAL N (µg/l)	SRP (µg/l)	TOTAL P (µg/l)	TSS (mg/l)
7/12/13	Column 1 A	90.4	x	x	657	x	118	x
	Column 1 B	99.0	x	x	605	x	130	x
	Column 1 C	95.4	x	x	2,848	x	76	x
	Column 2 A	86.0	x	x	1,537	x	103	x
	Column 2 B	88.2	x	x	1,515	x	125	x
	Column 2 C	82.8	x	x	4,049	x	95	x
	Column 3 A	105	x	x	394	x	171	x
	Column 3 B	112	x	x	759	x	190	x
	Column 3 C	107	x	x	3,524	x	154	x
	Influent I	84.8	x	x	860	x	206	x
	Influent II	x	x	x	4,407	x	x	x
7/25/13	Column 1 A	93.8	x	x	1,342	x	270	x
	Column 1 B	88.8	x	x	1,328	x	315	x
	Column 1 C	97.6	x	x	5,021	x	562	x
	Column 2 A	89.0	x	x	1,487	x	270	x
	Column 2 B	91.8	x	x	1,964	x	406	x
	Column 2 C	86.2	x	x	2,710	x	452	x
	Column 3 A	112	x	x	1,777	x	419	x
	Column 3 B	108	x	x	963	x	277	x
	Column 3 C	118	x	x	3,841	x	229	x
	Influent I	94.4	x	x	2,160	x	447	x
	Influent II	x	x	x	4,557	x	x	x
7/31/13	Column 1 A	x	x	x	1,037	x	98	x
	Column 1 B	x	x	x	1,027	x	111	x
	Column 1 C	x	x	x	4,146	x	142	x
	Column 2 A	x	x	x	1,356	x	191	x
	Column 2 B	x	x	x	1,598	x	232	x
	Column 2 C	x	x	x	4,191	x	313	x
	Column 3 A	x	x	x	855	x	202	x
	Column 3 B	x	x	x	3,948	x	170	x
	Column 3 C	x	x	x	1,120	x	150	x
	Influent I	x	x	x	910	x	248	x
	Influent II	x	x	x	2,417	x	x	x

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RESULTS OF SAMPLE ANALYSES CONDUCTED ON SAMPLES COLLECTED FOR THE "BAM" PROJECT -- UCF Project No. 16607051

DATE COLLECTED	SAMPLE DESCRIPTION	ALKALINITY (mg/l)	NO_x (µg/l)	NH_3 (µg/l)	TOTAL N (µg/l)	SRP (µg/l)	TOTAL P (µg/l)	TSS (mg/l)
8/1/13	Column 1 A	81.8	x	x	619	x	111	x
	Column 1 B	82.6	x	x	476	x	78	x
	Column 1 C	88.2	x	x	3,963	x	116	x
	Column 2 A	73.8	x	x	1,416	x	59	x
	Column 2 B	74.0	x	x	1,503	x	87	x
	Column 2 C	76.4	x	x	4,197	x	97	x
	Column 3 A	90.8	x	x	759	x	183	x
	Column 3 B	107	x	x	943	x	144	x
	Column 3 C	99.6	x	x	4,207	x	150	x
	Influent I	72.0	x	x	1,065	x	17	x
	Influent II	x	x	x	4,440	x	x	x
8/5/13	Column 1 A	64.2	x	x	371	x	81	x
	Column 1 B	58.6	x	x	313	x	81	x
	Column 1 C	62.8	x	x	3,357	x	88	x
	Column 2 A	52.2	x	x	946	x	74	x
	Column 2 B	50.6	x	x	1,106	x	98	x
	Column 2 C	53.8	x	x	3,548	x	92	x
	Column 3 A	76.8	x	x	574	x	179	x
	Column 3 B	73.4	x	x	460	x	149	x
	Column 3 C	76.4	x	x	3,537	x	175	x
	Influent I	44.2	x	x	1,040	x	154	x
	Influent II	x	x	x	3,642	x	x	x
8/7/13	Column 1 A	67.8	x	x	932	x	82	x
	Column 1 B	65.0	x	x	981	x	95	x
	Column 1 C	64.4	x	x	3,792	x	85	x
	Column 2 A	59.4	x	x	1,240	x	175	x
	Column 2 B	62.8	x	x	1,321	x	200	x
	Column 2 C	64.4	x	x	4,129	x	182	x
	Column 3 A	80.6	x	x	1,253	x	191	x
	Column 3 B	74.8	x	x	1,172	x	115	x
	Column 3 C	74.0	x	x	4,090	x	154	x
	Influent I	61.8	x	x	1,403	x	161	x
	Influent II	x	x	x	4,349	x	x	x

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RESULTS OF SAMPLE ANALYSES CONDUCTED ON SAMPLES COLLECTED FOR THE "BAM" PROJECT -- UCF Project No. 16607051

DATE COLLECTED	SAMPLE DESCRIPTION	ALKALINITY (mg/l)	NO_x (µg/l)	NH_3 (µg/l)	TOTAL N (µg/l)	SRP (µg/l)	TOTAL P (µg/l)	TSS (mg/l)
8/13/13	Column 1 A	91.4	x	x	410	x	115	x
	Column 1 B	88.8	x	x	407	x	112	x
	Column 1 C	94.6	x	x	3,203	x	120	x
	Column 2 A	94.1	x	x	1,019	x	108	x
	Column 2 B	89.6	x	x	1,135	x	115	x
	Column 2 C	82.8	x	x	3,777	x	100	x
	Column 3 A	95.6	x	x	897	x	154	x
	Column 3 B	102	x	x	3,680	x	160	x
	Column 3 C	108	x	x	499	x	155	x
	Influent I	83.8	x	x	1,135	x	148	x
	Influent II	x	x	x	3,546	x	x	x
8/15/13	Column 1 A	87.2	x	x	752	x	126	x
	Column 1 B	84.8	x	x	881	x	125	x
	Column 1 C	90.4	x	x	4,855	x	325	x
	Column 2 A	82.4	x	x	1,099	x	123	x
	Column 2 B	83.4	x	x	1,008	x	194	x
	Column 2 C	88.6	x	x	3,691	x	190	x
	Column 3 A	96.4	x	x	885	x	156	x
	Column 3 B	95.8	x	x	536	x	111	x
	Column 3 C	104	x	x	3,557	x	152	x
	Influent I	82.2	x	x	1,306	x	152	x
	Influent II	x	x	x	3,757	x	x	x
8/27/13	Column 1 A	57.2	x	x	1,078	x	273	x
	Column 1 B	56.8	x	x	1,029	x	397	x
	Column 1 C	60.2	x	x	4,154	x	235	x
	Column 2 A	49.4	x	x	1,456	x	148	x
	Column 2 B	54.0	x	x	1,451	x	135	x
	Column 2 C	50.6	x	x	4,609	x	824	x
	Column 3 A	76.4	x	x	1,178	x	213	x
	Column 3 B	78.2	x	x	956	x	203	x
	Column 3 C	53.4	x	x	3,880	x	203	x
	Influent I	84.2	x	x	1,598	x	469	x
	Influent II	x	x	x	3,581	x	x	x

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RESULTS OF SAMPLE ANALYSES CONDUCTED ON SAMPLES COLLECTED FOR THE "BAM" PROJECT -- UCF Project No. 16607051

DATE COLLECTED	SAMPLE DESCRIPTION	ALKALINITY (mg/l)	NO_x (µg/l)	NH_3 (µg/l)	TOTAL N (µg/l)	SRP (µg/l)	TOTAL P (µg/l)	TSS (mg/l)
8/29/13	Column 1 A	x	x	710	1,693	x	215	x
	Column 1 B	x	x	474	1,538	x	299	x
	Column 1 C	x	x	736	4,474	x	337	x
	Column 2 A	x	x	558	1,504	x	180	x
	Column 2 B	x	x	542	1,593	x	236	x
	Column 2 C	x	x	786	4,468	x	247	x
	Column 3 A	x	x	556	1,467	x	199	x
	Column 3 B	x	x	N/A	N/A	x	N/A	x
	Column 3 C	x	x	1,027	4,335	x	145	x
	Influent I	x	x	657	1,683	x	256	x
	Influent II	x	x	872	4,416	x	247	x
9/3/13	Column 1 A	x	x	321	787	x	149	x
	Column 1 B	x	x	351	802	x	120	x
	Column 1 C	x	x	867	4,074	x	184	x
	Column 2 A	x	x	255	1,226	x	237	x
	Column 2 B	x	x	133	1,221	x	194	x
	Column 2 C	x	x	967	3,781	x	150	x
	Column 3 A	x	x	262	1,002	x	197	x
	Column 3 B	x	x	467	867	x	225	x
	Column 3 C	x	x	868	3,837	x	200	x
	Influent I	x	x	689	1,483	x	252	x
	Influent II	x	x	729	4,157	x	210	x
9/24/13	Column 1 A	61.4	22	673	1,382	26	262	x
	Column 1 B	50.8	14	283	4,821	26	7,854	x
	Column 1 C	46.2	26	899	4,412	32	330	x
	Column 2 A	46.8	719	111	1,110	131	271	x
	Column 2 B	41.4	653	164	1,089	145	253	x
	Column 2 C	44.8	116	847	4,209	128	182	x
	Column 3 A	64.0	377	241	1,755	136	207	x
	Column 3 B	65.0	165	324	923	140	230	x
	Column 3 C	64.0	44	1,192	3,508	188	262	x
	Influent I	72.4	308	659	1,267	190	209	x
	Influent II	x	251	770	4,133	200	243	x

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RESULTS OF SAMPLE ANALYSES CONDUCTED ON SAMPLES COLLECTED FOR THE "BAM" PROJECT -- UCF Project No. 16607051

DATE COLLECTED	SAMPLE DESCRIPTION	ALKALINITY (mg/l)	NO_x (µg/l)	NH_3 (µg/l)	TOTAL N (µg/l)	SRP (µg/l)	TOTAL P (µg/l)	TSS (mg/l)
9/27/13	Column 1 A	79.2	326	415	1,161	68	121	x
	Column 1 B	79.8	375	390	1,106	78	138	x
	Column 1 C	82.6	174	597	4,492	70	123	x
	Column 2 A	78.0	450	523	1,442	144	167	x
	Column 2 B	78.8	463	456	1,594	143	296	x
	Column 2 C	83.2	209	827	4,407	140	190	x
	Column 3 A	95.0	451	371	1,374	119	137	x
	Column 3 B	98.2	493	361	1,468	101	118	x
	Column 3 C	107	176	778	4,634	111	124	x
	Influent I	82.6	244	649	2,023	179	276	x
	Influent II	x	230	672	4,900	192	250	x
10/1/13	Column 1 A	105	9	333	904	79	161	x
	Column 1 B	104	31	241	823	55	207	x
	Column 1 C	109	11	816	3,849	58	122	x
	Column 2 A	104	618	281	1,355	123	150	x
	Column 2 B	99.8	418	355	1,149	116	142	x
	Column 2 C	98.4	50	1,190	4,504	112	161	x
	Column 3 A	70.4	175	251	1,476	139	184	x
	Column 3 B	127.0	81	175	570	142	188	x
	Column 3 C	68.0	17	821	4,010	160	192	x
	Influent I	63.8	515	609	1,664	132	209	x
	Influent II	x	280	824	4,391	144	193	x
10/4/13	Column 1 A	103	473	256	1,165	59	84	x
	Column 1 B	102	547	268	1,380	58	84	x
	Column 1 C	98.2	173	656	2,730	51	275	x
	Column 2 A	97.2	644	441	1,487	126	175	x
	Column 2 B	97.4	634	241	1,440	128	273	x
	Column 2 C	99.2	208	856	4,522	120	701	x
	Column 3 A	115	579	298	1,336	95	103	x
	Column 3 B	120	517	317	1,315	90	103	x
	Column 3 C	114	174	777	4,132	90	105	x
	Influent I	101	325	942	1,586	149	250	x
	Influent II	x	230	904	4,264	145	254	x

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DATE COLLECTED	SAMPLE DESCRIPTION	ALKALINITY (mg/l)	NO_x (µg/l)	NH_3 (µg/l)	TOTAL N (µg/l)	SRP (µg/l)	TOTAL P (µg/l)	TSS (mg/l)
10/8/13	Column 1 A	82.4	21	261	740	128	145	x
	Column 1 B	76.2	20	78	551	103	106	x
	Column 1 C	77.0	4	728	3,828	88	131	x
	Column 2 A	71.0	801	60	1,260	161	180	x
	Column 2 B	74.8	636	131	1,042	172	181	x
	Column 2 C	75.2	196	791	3,720	153	183	x
	Column 3 A	98.6	289	34	755	124	185	x
	Column 3 B	93.6	158	85	628	205	235	x
	Column 3 C	96.8	19	646	3,586	179	190	x
	Influent I	64.0	329	735	1,444	213	226	x
	Influent II	x	247	719	4,102	227	445	x
10/16/13	Column 1 A	99.4	17	382	846	109	231	x
	Column 1 B	93.4	13	260	734	95	450	x
	Column 1 C	114	9	886	4,200	93	259	x
	Column 2 A	96.0	221	312	1,034	120	214	x
	Column 2 B	98.4	21	524	924	110	303	x
	Column 2 C	103	81	820	3,816	136	245	x
	Column 3 A	122	27	574	1,097	186	297	x
	Column 3 B	118	53	648	1,120	264	419	x
	Column 3 C	83.4	12	1,209	4,635	202	328	x
	Influent I	81.8	233	815	1,781	163	315	x
	Influent II	x	229	792	4,198	172	306	x
10/18/13	Column 1 A	93.2	470	244	1,465	97	110	x
	Column 1 B	91.0	397	352	1,480	101	124	x
	Column 1 C	95.4	141	712	4,285	100	117	x
	Column 2 A	91.6	444	450	1,455	142	161	x
	Column 2 B	88.2	446	468	1,559	137	171	x
	Column 2 C	94.4	179	762	4,287	158	189	x
	Column 3 A	103	525	381	1,601	133	168	x
	Column 3 B	108	420	403	1,427	127	142	x
	Column 3 C	97.2	135	796	4,311	118	123	x
	Influent I	80.4	215	708	1,768	189	245	x
	Influent II	x	204	679	4,522	182	250	x

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DATE COLLECTED	SAMPLE DESCRIPTION	ALKALINITY (mg/l)	NO_x (µg/l)	NH_3 (µg/l)	TOTAL N (µg/l)	SRP (µg/l)	TOTAL P (µg/l)	TSS (mg/l)
10/23/13	Column 1 A	105	17	126	806	30	116	x
	Column 1 B	104	8	160	437	47	151	x
	Column 1 C	109	6	754	4,017	42	123	x
	Column 2 A	103	395	184	1,088	73	97	x
	Column 2 B	101	154	351	714	87	161	x
	Column 2 C	108	93	708	3,801	86	123	x
	Column 3 A	125	152	146	1,020	89	144	x
	Column 3 B	126	16	178	666	117	158	x
	Column 3 C	123	5	373	1,637	120	156	x
	Influent I	101	240	740	906	164	203	x
	Influent II	x	264	530	4,349	169	210	x
10/25/13	Column 1 A	97.8	267	398	1,175	89	121	x
	Column 1 B	80.4	314	359	1,186	94	126	x
	Column 1 C	83.4	167	695	3,894	100	171	x
	Column 2 A	85.4	306	441	1,368	151	195	x
	Column 2 B	80.4	371	429	1,419	142	172	x
	Column 2 C	84.2	173	698	3,923	155	200	x
	Column 3 A	95.2	413	513	1,308	132	153	x
	Column 3 B	95.0	338	538	1,193	109	142	x
	Column 3 C	91.8	163	754	3,895	78	100	x
	Influent I	83.0	208	643	1,600	182	233	x
	Influent II	x	196	658	3,963	169	203	x
10/29/13	Column 1 A	96.8	70	236	786	53	99	x
	Column 1 B	92.0	26	280	755	66	101	x
	Column 1 C	95.8	5	621	4,579	82	125	x
	Column 2 A	85.4	757	129	1,357	107	113	x
	Column 2 B	88.6	561	239	1,309	105	143	x
	Column 2 C	90.0	132	928	4,381	101	112	x
	Column 3 A	106	330	410	1,371	142	139	x
	Column 3 B	117	298	375	1,244	167	172	x
	Column 3 C	117	33	1,045	4,296	165	174	x
	Influent I	85.0	258	793	1,623	185	198	x
	Influent II	x	229	956	4,648	187	200	x

Analytical results presented in this report have been reviewed for compliance with the ENVIRONMENTAL RESEARCH & DESIGN, INC. (ERD) Quality Systems Manual and have been determined to meet applicable method guidelines and standards referenced in the July 2003 National Environmental laboratory Accreditation Program (NELAP) Quality Manual unless otherwise noted. The Analytical Results within these report pages reflect the values obtained from tests performed on samples as received by the laboratory unless indicated differently.

Cassie Pelto
Cassie Pelto
Lab Director

NELAC No. E1031026

ENVIRONMENTAL RESEARCH & DESIGN, INC.
Engineering • Science • Chemistry • Research
3419 Trentwood Blvd. • Suite 102 • Belle Isle (Orlando), FL 32812-4864
Telephone: 407-855-9465 • Fax: 407-826-0419

RESULTS OF SAMPLE ANALYSES CONDUCTED ON SAMPLES COLLECTED FOR THE "BAM" PROJECT -- UCF Project No. 16607051

DATE COLLECTED	SAMPLE DESCRIPTION	ALKALINITY (mg/l)	NO_x (µg/l)	NH_3 (µg/l)	TOTAL N (µg/l)	SRP (µg/l)	TOTAL P (µg/l)	TSS (mg/l)
11/1/13	Column 1 A	92.0	296	492	1,145	78	109	x
	Column 1 B	87.4	416	448	1,675	86	116	x
	Column 1 C	96.6	170	904	4,484	68	92	x
	Column 2 A	86.8	398	576	1,298	139	172	x
	Column 2 B	88.4	409	537	1,417	130	196	x
	Column 2 C	94.2	194	883	4,815	137	230	x
	Column 3 A	95.2	486	426	1,239	122	152	x
	Column 3 B	102	426	492	1,213	124	128	x
	Column 3 C	105	166	929	4,530	77	96	x
	Influent I	98.2	206	858	1,533	164	245	x
	Influent II	x	208	899	4,834	165	239	x
11/5/13	Column 1 A	94.8	13	204	755	62	116	x
	Column 1 B	102	66	116	797	40	114	x
	Column 1 C	101	21	536	4,007	37	67	x
	Column 2 A	91.6	651	79	1,294	87	113	x
	Column 2 B	88.4	457	161	1,150	81	131	x
	Column 2 C	94.0	161	545	4,119	97	109	x
	Column 3 A	112	278	104	880	102	177	x
	Column 3 B	113	152	66	778	136	155	x
	Column 3 C	110	24	484	3,657	110	134	x
	Influent I	90.6	261	660	1,594	184	205	x
	Influent II	x	224	760	2,720	182	205	x
11/8/13	Column 1 A	96.4	364	328	1,152	92	115	x
	Column 1 B	94.2	501	229	1,192	78	104	x
	Column 1 C	104	189	579	4,078	123	96	x
	Column 2 A	89.0	495	366	1,401	164	213	x
	Column 2 B	91.0	520	331	1,459	149	175	x
	Column 2 C	95.4	214	653	4,005	170	211	x
	Column 3 A	102	594	200	1,327	114	122	x
	Column 3 B	100	524	267	1,305	103	113	x
	Column 3 C	106	212	622	4,003	102	58	x
	Influent I	92.2	238	640	1,653	203	221	x
	Influent II	x	226	644	4,253	196	203	x

Analytical results presented in this report have been reviewed for compliance with the ENVIRONMENTAL RESEARCH & DESIGN, INC. (ERD) Quality Systems Manual and have been determined to meet applicable method guidelines and standards referenced in the July 2003 National Environmental laboratory Accreditation Program (NELAP) Quality Manual unless otherwise noted. The Analytical Results within these report pages reflect the values obtained from tests performed on samples as received by the laboratory unless indicated differently.

Cassie Pelto
Cassie Pelto
Lab Director

NELAC No. E1031026

ENVIRONMENTAL RESEARCH & DESIGN, INC.

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RESULTS OF SAMPLE ANALYSES CONDUCTED ON SAMPLES COLLECTED FOR THE "BAM" PROJECT -- UCF Project No. 16607051

DATE COLLECTED	SAMPLE DESCRIPTION	ALKALINITY (mg/l)	NO_x (µg/l)	NH_3 (µg/l)	TOTAL N (µg/l)	SRP (µg/l)	TOTAL P (µg/l)	TSS (mg/l)
11/13/13	Column 1 A	98.2	306	113	1,028	59	112	x
	Column 1 B	108	650	51	946	61	116	x
	Column 1 C	109	22	676	4,141	65	109	x
	Column 2 A	96.4	1,047	85	1,617	148	222	x
	Column 2 B	92.8	832	189	1,557	91	145	x
	Column 2 C	104	236	742	4,314	111	134	x
	Column 3 A	94.0	581	75	1,196	133	166	x
	Column 3 B	117	494	149	1,093	146	181	x
	Column 3 C	127	69	824	4,151	128	146	x
	Influent I	101	348	763	1,747	192	220	x
	Influent II	x	270	898	4,359	203	240	x
11/15/13	Column 1 A	100	395	350	1,182	99	136	x
	Column 1 C	100	196	650	3,925	84	109	x
	Column 2 A	93.2	519	343	1,380	139	161	x
	Column 2 B	92.8	542	329	1,281	130	172	x
	Column 2 C	92.6	217	728	4,171	146	306	x
	Column 3 A	105	599	192	1,273	117	148	x
	Column 3 B	104	562	298	1,339	111	130	x
	Column 3 C	110	203	652	3,957	110	124	x
	Influent I	96.2	237	618	1,491	147	173	x
	Influent II	x	234	693	4,375	154	185	x
11/19/13	Column 1 A	103	133	3	598	33	78	x
	Column 1 B	94.2	430	3	854	35	61	x
	Column 1 C	100	23	454	3,324	35	65	x
	Column 2 A	94.6	714	3	1,220	76	116	x
	Column 2 B	95.0	943	3	1,459	99	246	x
	Column 2 C	100	211	603	3,908	126	175	x
	Column 3 A	110	507	3	1,072	77	119	x
	Column 3 B	116	538	3	1,057	70	86	x
	Column 3 C	116	38	453	3,383	97	113	x
	Influent I	112	330	571	1,528	158	182	x
	Influent II	x	228	729	4,255	174	201	x

Analytical results presented in this report have been reviewed for compliance with the ENVIRONMENTAL RESEARCH & DESIGN, INC. (ERD) Quality Systems Manual and have been determined to meet applicable method guidelines and standards referenced in the July 2003 National Environmental laboratory Accreditation Program (NELAP) Quality Manual unless otherwise noted. The Analytical Results within these report pages reflect the values obtained from tests performed on samples as received by the laboratory unless indicated differently.

Cassie Pelto
Cassie Pelto
Lab Director

NELAC No. E1031026

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RESULTS OF SAMPLE ANALYSES CONDUCTED ON SAMPLES COLLECTED FOR THE "BAM" PROJECT -- UCF Project No. 16607051

DATE COLLECTED	SAMPLE DESCRIPTION	ALKALINITY (mg/l)	NO_x (µg/l)	NH_3 (µg/l)	TOTAL N (µg/l)	SRP (µg/l)	TOTAL P (µg/l)	TSS (mg/l)
11/19/13	Column 1 A – 2 Hr Grab	x	2	x	x	x	x	x
	Column 1 A – 2 Hr Tub	x	15	x	x	x	x	x
	Column 1 A - 24 Hr Grab	x	73	x	x	x	x	x
	Column 2 A – 2 Hr Grab	x	487	x	x	x	x	x
	Column 2 A – 2 Hr Tub	x	179	x	x	x	x	x
	Column 2 A - 24 Hr Grab	x	822	x	x	x	x	x
	Column 3 A – 2 Hr Grab	x	332	x	x	x	x	x
	Column 3 A – 2 Hr Tub	x	148	x	x	x	x	x
	Column 3 A - 24 Hr Grab	x	538	x	x	x	x	x
11/22/13	Column 1 A	89.2	493	412	1,392	96	121	x
	Column 1 B	92.4	616	274	1,320	100	123	x
	Column 1 C	93.4	225	682	4,042	96	107	x
	Column 2 A	88.4	632	331	1,405	133	462	x
	Column 2 B	91.6	618	362	1,523	145	316	x
	Column 2 C	96.2	x	760	3,861	NA	360	x
	Column 3 A	100	775	161	1,306	110	135	x
	Column 3 B	99.2	712	283	1,359	87	122	x
	Column 3 C	103	233	658	3,909	87	122	x
	Influent I	96.4	344	780	1,672	163	266	x
	Influent II	x	271	845	4,128	171	267	x

Analytical results presented in this report have been reviewed for compliance with the ENVIRONMENTAL RESEARCH & DESIGN, INC. (ERD) Quality Systems Manual and have been determined to meet applicable method guidelines and standards referenced in the July 2003 National Environmental laboratory Accreditation Program (NELAP) Quality Manual unless otherwise noted. The Analytical Results within these report pages reflect the values obtained from tests performed on samples as received by the laboratory unless indicated differently.

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RESULTS OF SAMPLE ANALYSES CONDUCTED ON SAMPLES COLLECTED FOR THE "BAM" PROJECT -- UCF Project No. 16607051

DATE COLLECTED	SAMPLE DESCRIPTION	ALKALINITY (mg/l)	NO_x (µg/l)	NH_3 (µg/l)	TOTAL N (µg/l)	SRP (µg/l)	TOTAL P (µg/l)	TSS (mg/l)
12/3/13	Column 1 A	106	282	3	711	18	75	x
	Column 1 B	104	324	3	926	19	177	x
	Column 1 C	102	35	690	3,954	43	97	x
	Column 2 A	96.0	959	3	1,268	95	110	x
	Column 2 B	94.8	931	3	1,610	116	224	x
	Column 2 C	96.0	220	483	3,937	122	203	x
	Column 3 A	115	450	3	468	95	115	x
	Column 3 B	118	555	3	608	96	102	x
	Column 3 C	117	43	611	4,146	145	134	x
	Influent I	99.0	261	492	834	175	176	x
	Influent II	x	232	608	4,195	183	202	x
12/6/13	Column 1 A	107	408	239	1,295	92	158	x
	Column 1 B	106	551	100	1,263	101	117	x
	Column 1 C	107	199	484	4,218	75	92	x
	Column 2 A	106	498	207	1,313	129	174	x
	Column 2 B	103	561	204	1,382	165	304	x
	Column 2 C	103	2,533	531	4,174	161	424	x
	Column 3 A	115	593	108	1,259	19	126	x
	Column 3 B	113	541	144	1,258	132	136	x
	Column 3 C	112	209	509	4,338	105	109	x
	Influent I	112	256	482	1,548	188	166	x
	Influent II	x	237	479	2,914	188	157	x
12/11/13	Column 1 A	106	384	247	1,338	95	104	x
	Column 1 B	107	542	106	1,453	103	128	x
	Column 1 C	108	190	502	4,028	74	77	x
	Column 2 A	108	510	295	1,542	153	353	x
	Column 2 B	105	509	296	1,003	163	304	x
	Column 2 C	111	216	710	4,211	160	493	x
	Column 3 A	117	602	146	1,282	114	121	x
	Column 3 B	113	555	160	747	114	112	x
	Column 3 C	123	184	688	4,178	120	134	x
	Influent I	111	233	718	1,421	177	186	x
	Influent II	x	236	736	4,322	174	181	x

Analytical results presented in this report have been reviewed for compliance with the ENVIRONMENTAL RESEARCH & DESIGN, INC. (ERD) Quality Systems Manual and have been determined to meet applicable method guidelines and standards referenced in the July 2003 National Environmental laboratory Accreditation Program (NELAP) Quality Manual unless otherwise noted. The Analytical Results within these report pages reflect the values obtained from tests performed on samples as received by the laboratory unless indicated differently.

Cassie Pelto
Cassie Pelto
Lab Director

NELAC No. E1031026

Page No. __

ENVIRONMENTAL RESEARCH & DESIGN INC. ----- CHAIN-OF-CUSTODY RECORD

3419 Trentwood Blvd., Suite 102 - Orlando, FL 32812 - Phone: (407) 855-9465 - Fax: (407) 826-0419

Client Name: UCF Storm Water Academy

Address:

Project Manager: Andrew Hood ~~Mike Harden/ Manoj Chopra~~ AF 6/7/13 Phone:

Project Name: BAM Project Number:

Containers Accepted By: Andrew Folkes

Samples Collected By: Andrew Hood

IDENTIFIER CODES / NUMBER OF SAMPLE BOTTLES COLLECTED

Sample I.D.	*Matrix	**IPC	ERD Sample I.D. No.	Date Collected	Time Collected	1- Gallon Plastic (BP)	1-Liter Glass	60 mL Plastic (Filtered) (F)	60 mL Plastic (Filtered/ Preserved w/ H_2SO_4) (FP)	60 mL Plastic (Preserved w/ H_2SO_4) (P)	250 ml Plastic (SP) (SP)	Glass (Preserved w/ HCl) (OG)	Metals: UF (M)	250 ml Plastic (Preserved w/ HNO_3) F (FM)	Whirlpak (W)	Other	Other
Number of bottles							10	10		10							
Column 1 A	SW	A	13-1948	6/6/13	1500		2,5	20,21		22,23,24							
Column 1 B	SW	A	13-1949	6/6/13	1500		2,5	20,21		22,23,24							
Column 1 C	SW	A	13-1950	6/6/13	1500		2,5	20,21		22,23,24							
Column 2 A	SW	A	13-1951	6/6/13	1500		2,5	20,21		22,23,24							
Column 2 B	SW	A	13-1952	6/6/13	1500		2,5	20,21		22,23,24							
Column 2 C	SW	A	13-1953	6/6/13	1500		2,5	20,21		22,23,24							
Column 3 A	SW	A	13-1954	6/6/13	1500		2,5	20,21		22,23,24							
Column 3 B	SW	A	13-1955	6/6/13	1500		2,5	20,21		22,23,24							
Column 3 C	SW	A	13-1956	6/6/13	1500		2,5	20,21		22,23,24							
Influent 1,2	SW	A	13-1957	6/6/13	1500		2,5	20,21		22,23,24							
Influent 3	SW	A	13-1958	6/6/13	1500		2,5	20,21		22,23,24							
DISPOSAL DATE:								KH 7.10		KH 7.10							

COMMENTS:

CUSTODY TRANSFERS			
Relinquished By	Received By	Date	Time
1. Andrew C. Hood	A. Folkes	6/7/13	1350
2.			

Method of Shipment:

Delivered Directly to Lab: X

Shipped By FedEx: ____ UPS: ____ Other: ____

Received in Cooler: ✓ Y __ N

Temperature: 4 °C

Shipped in Ice: ✓ Y __ N

Ice Present: ✓ Y __ N

pH Checked in Laboratory (< 2 s.u.): ✓ Y __ N

Chlorine Check (< 0.1 mg/l): __ Y ✓ N

*MATRIX: SW=Stormwater SP=Seepage S=Surface Water BF=Baseflow GW=Groundwater BP=Bulk Precipitation G=Grab C=Composite

**ICE PRESERVATION CODES (IPC): A=Transported on ice, ice present when received B=Transported on ice, ice not present when received C=Not transported on ice

Page No. __

ENVIRONMENTAL RESEARCH & DESIGN, INC. ----- CHAIN-OF-CUSTODY RECORD

3419 Trentwood Blvd., Suite 102 - Orlando, FL 32812 - Phone: (407) 855-9465 - Fax: (407) 826-0419

Client Name: UCF Storm Water Academy

Address:

Project Manager: Mike Harden/ Manoj Chopra Phone:

Project Name: BAM Project Number:

Containers Accepted By: Cassie Pelto

Samples Collected By: Andrew Hood / Michael Depree

IDENTIFIER CODES / NUMBER OF SAMPLE BOTTLES COLLECTED

Sample I.D.	*Matrix	**IPC	ERD Sample I.D. No.	Date Collected	Time Collected	1- Gallon Plastic (BP)	1-Liter Glass	60 mL Plastic (Filtered)	60 mL Plastic (Filtered/ Preserved w/ H_2SO_4)	60 mL Plastic (Preserved w/ H_2SO_4)	250 ml Plastic (SP)	Glass (Preserved w/ HCl)	Metals: 250 ml Plastic (Preserved w/ HNO_3) UF	Metals: 250 ml Plastic (Preserved w/ HNO_3) F	Whirlpak	Other	Other
Identifier code								F	FP	P	SP	OG	M	FM	W		
Number of bottles							10	10		10							
Column 1 A	SW	A	13-1520	5/1/13	1500		2,5	20,21		22,23,24							
Column 1 B	SW	A	1521	5/1/13	1500		2,5	20,21		22,23,24							
Column 1 C	SW	A	1522	5/1/13	1500		2,5	20,21		22,23,24							
Column 2 A	SW	A	1523	5/1/13	1500		2,5	20,21		22,23,24							
Column 2 B	SW	A	1524	5/1/13	1500		2,5	20,21		22,23,24							
Column 2 C	SW	A	1525	5/1/13	1500		2,5	20,21		22,23,24							
Column 3 A	SW	A	1526	5/1/13	1500		2,5	20,21		22,23,24							
Column 3 B	SW	A	1527	5/1/13	1500		2,5	20,21		22,23,24							
Column 3 C	SW	A	1528	5/1/13	1500		2,5	20,21		22,23,24							
Influent	SW	A	1529	5/1/13	1500		2,5	20,21		22,23,24							
				DISPOSAL DATE:													

COMMENTS:

CUSTODY TRANSFERS

Relinquished By	Received By	Date	Time
1. Michael Depree	[signature]	5/2/13	1300
2.			

Method of Shipment:

Delivered Directly to Lab: X

Shipped By FedEx: ____ UPS: ____ Other: ____

Received in Cooler: ✓ Y ___ N

Temperature: 4 °C

Shipped in Ice: ✓ Y ___ N

Ice Present: ✓ Y ___ N

pH Checked in Laboratory (< 2 s.u.): ✓ Y ___ N

Chlorine Check (< 0.1 mg/l): ___ Y ✓ N

*MATRIX: SW=Stormwater SP=Seepage S=Surface Water BF=Baseflow GW=Groundwater BP=Bulk Precipitation G=Grab C=Composite

**ICE PRESERVATION CODES (IPC): A=Transported on ice, ice present when received B=Transported on ice, ice not present when received C=Not transported on ice

Page No ___

ENVIRONMENTAL RESEARCH & DESIG INC. ---- CHAIN-OF-CUSTODY RECORD
3419 Trentwood Blvd., Suite 102 - Orlando, FL 32812 - Phone: (407) 855-9465 - Fax: (407) 826-0419

Client Name: UCF Storm Water Academy

Address:

Project Manager: Andrew Hood Phone:

Project Name: BAM Project Number:

Containers Accepted By:

Samples Collected By: Andrew Hood

Sample I.D.	*Matrix	**IPC	ERD Sample I.D. No.	Date Collected	Time Collected	1- Gallon Plastic (BP)	1-Liter Glass	60 mL Plastic (Filtered)	60 mL Plastic (Filtered/ Preserved w/ H_2SO_4)	60 mL Plastic (Preserved w/ H_2SO_4)	250 ml Plastic (SP)	Glass (Preserved w/ HCl)	Metals: 250 ml Plastic (Preserved w/ HNO_3) UF	Metals: 250 ml Plastic (Preserved w/ HNO_3) F	Whirlpak	Other	Other
Identifier codes								F	FP	P	SP	OG	M	FM	W		
Number of sample bottles collected							10	10		10							
Column 1 A	SW	A	13-2034	6/13/13	1500		2,5	20,21		22,23,24			51,52,53				
Column 1 B	SW	A	2035	6/13/13	1500		2,5	20,21		22,23,24							
Column 1 C	SW	A	2036	6/13/13	1500		2,5	20,21		22,23,24							
Column 2 A	SW	A	2037	6/13/13	1500		2,5	20,21		22,23,24							
Column 2 B	SW	A	2038	6/13/13	1500		2,5	20,21		22,23,24							
Column 2 C	SW	A	2039	6/13/13	1500		2,5	20,21		22,23,24							
Column 3 A	SW	A	2040	6/13/13	1500		2,5	20,21		22,23,24							
Column 3 B	SW	A	2041	6/13/13	1500		2,5	20,21		22,23,24							
Column 3 C	SW	A	2042	6/13/13	1500		2,5	20,21		22,23,24							
Influent 1,2	SW	A	2043	6/13/13	1500		2,5	20,21		22,23,24							
Influent 3	SW	A	2044	6/13/13	1500			21		22,23							
					DISPOSAL DATE:												

COMMENTS:

CUSTODY TRANSFERS			
Relinquished By	Received By	Date	Time
1. Andrew C. Hood	[illegible]	6/14/13	1415
2.			

Method of Shipment:
Delivered Directly to Lab: X
Shipped By FedEx: ___ UPS: ___ Other: ___

Received in Cooler: ✓ Y ___ N
Temperature: 4 °C
Shipped in Ice: ✓ Y ___ N
Ice Present: ✓ Y ___ N

pH Checked in Laboratory (< 2 s.u.): ✓ Y ___ N
Chlorine Check (< 0.1 mg/l): ___ Y ✓ N
CP 6/13

*MATRIX: SW=Stormwater SP=Seepage S=Surface Water BF=Baseflow GW=Groundwater BP=Bulk Precipitation G=Grab C=Composite
**ICE PRESERVATION CODES (IPC): A=Transported on ice, ice present when received B=Transported on ice, ice not present when received C=Not transported on ice

Page No. ____

ENVIRONMENTAL RESEARCH & DESIGN, INC. ----- CHAIN-OF-CUSTODY RECORD

3419 Trentwood Blvd., Suite 102 - Orlando, FL 32812 - Phone: (407) 855-9465 - Fax: (407) 826-0419

Client Name: UCF Storm Water Academy

Address:

Project Manager: Andrew Hood Phone:

Project Name: BAM Project Number:

Containers Accepted By:

Samples Collected By: Andrew Hood

Sample I.D.	*Matrix	**IPC	ERD Sample I.D. No.	Date Collected	Time Collected	1- Gallon Plastic (BP)	1-Liter Glass	60 mL Plastic (Filtered)	60 mL Plastic (Filtered/ Preserved w/ H_2SO_4)	60 mL Plastic (Preserved w/ H_2SO_4)	250 ml Plastic (SP)	Glass (Preserved w/ HCl)	Metals: UF	250 ml Plastic (Preserved w/ HNO_3) F	Whirlpak	Other ____	Other ____
IDENTIFIER CODES								F	FP	P	SP	OG	M	FM	W		
NUMBER OF SAMPLE BOTTLES COLLECTED							10	10		10							
Column 1 A	SW	A	13-2158	6/20/13	1300		2,5	20,21		22,23,24							
Column 1 B	SW	A	2159	6/20/13	1300		2,5	20,21		22,23,24							
Column 1 C	SW	A	2160	6/20/13	1300		2,5	20,21		22,23,24							
Column 2 A	SW	A	2161	6/20/13	1300		2,5	20,21		22,23,24							
Column 2 B	SW	A	2162	6/20/13	1300		2,5	20,21		22,23,24							
Column 2 C	SW	A	2163	6/20/13	1300		2,5	20,21		22,23,24							
Column 3 A	SW	A	2164	6/20/13	1300		2,5	20,21		22,23,24							
Column 3 B	SW	A	2165	6/20/13	1300		2,5	20,21		22,23,24							
Column 3 C	SW	A	2166	6/20/13	1300		2,5	20,21		22,23,24							
Influent 1,2	SW	A	2167	6/20/13	1300		2,5	20,21		22,23,24							
Influent 3	SW	A	13-2168	6/20/13	1300					23							
					DISPOSAL DATE:			8/15/13CK		8/15/13CK							

COMMENTS:

CUSTODY TRANSFERS			
Relinquished By	Received By	Date	Time
1. Zc	Ambum	6/21/13	1056
2.			

Method of Shipment:

Delivered Directly to Lab: X

Shipped By FedEx: ____ UPS: ____ Other: ____

Received in Cooler: ✓ Y ___ N

Temperature: 4 °C

Shipped in Ice: ✓ Y ___ N

Ice Present: ✓ Y ___ N

pH Checked in Laboratory (< 2 s.u.): ✓ Y ___ N

Chlorine Check (< 0.1 mg/l): ___ Y ✓ N

*MATRIX: SW=Stormwater SP=Seepage S=Surface Water BF=Baseflow GW=Groundwater BP=Bulk Precipitation G=Grab C=Composite

**ICE PRESERVATION CODES (IPC): A=Transported on ice, ice present when received B=Transported on ice, ice not present when received C=Not transported on ice

Page No. __

ENVIRONMENTAL RESEARCH & DESIGN, INC. ----- CHAIN-OF-CUSTODY RECORD

3419 Trentwood Blvd., Suite 102 - Orlando, FL 32812 - Phone: (407) 855-9465 - Fax: (407) 826-0419

Client Name: UCF Storm Water Academy

Address:

Project Manager: Andrew Hood Phone:

Project Name: BAM Project Number:

Containers Accepted By:

Samples Collected By: Andrew Hood

						IDENTIFIER CODES											
								F	FP	P	SP	OG	M	FM	W		
						NUMBER OF SAMPLE BOTTLES COLLECTED											
							10	10		11							
Sample I.D.	*Matrix	**IPC	ERD Sample I.D. No.	Date Collected	Time Collected	1- Gallon Plastic (BP)	1-Liter Glass	60 mL Plastic (Filtered)	60 mL Plastic (Filtered/ Preserved w/ H_2SO_4)	60 mL Plastic (Preserved w/ H_2SO_4)	250 ml Plastic (SP)	Glass (Preserved w/ HCl)	Metals: UF	250 ml Plastic (Preserved w/ HNO_3) F	Whirlpak	Other ___	Other ___
Column 1 A	SW	A	13-2297	6/26/13	1300		2,5	20,21		22,23,24							
Column 1 B	SW	A	2298	6/26/13	1300		2,5	20,21		22,23,24							
Column 1 C	SW	A	2299	6/26/13	1300		2,5	20,21		22,23,24							
Column 2 A	SW	A	2300	6/26/13	1300		2,5	20,21		22,23,24							
Column 2 B	SW	A	2301	6/26/13	1300		2,5	20,21		22,23,24							
Column 2 C	SW	A	2302	6/26/13	1300		2,5	20,21		22,23,24							
Column 3 A	SW	A	2303	6/26/13	1300		2,5	20,21		22,23,24							
Column 3 B	SW	A	2304	6/26/13	1300		2,5	20,21		22,23,24							
Column 3 C	SW	A	2305	6/26/13	1300		2,5	20,21		22,23,24							
Influent I	SW	A	2306	6/26/13	1300		2,5	20,21		22,23,24							
Influent II	SW	A	2307	6/26/13	1300					23							
				DISPOSAL DATE:													

COMMENTS:

CUSTODY TRANSFERS			
Relinquished By	Received By	Date	Time
1. Scott [signature]	[signature]	6/27/13	1315
2.			

Method of Shipment:

Delivered Directly to Lab: X

Shipped By FedEx: ____ UPS: ____ Other: ____

Received in Cooler: ✓ Y ___ N

Temperature: 4 °C

Shipped in Ice: ✓ Y ___ N

Ice Present: ✓ Y ___ N

pH Checked in Laboratory (< 2 s.u.): ___ Y ___ N

Chlorine Check (< 0.1 mg/l): ___ Y ✓ N

*MATRIX: SW=Stormwater SP=Seepage S=Surface Water BF=Baseflow GW=Groundwater BP=Bulk Precipitation G=Grab C=Composite

**ICE PRESERVATION CODES (IPC): A=Transported on ice, ice present when received B=Transported on ice, ice not present when received C=Not transported on ice

Page No. ___

ENVIRONMENTAL RESEARCH & DESIGN, INC. ----- CHAIN-OF-CUSTODY RECORD

3419 Trentwood Blvd., Suite 102 - Orlando, FL 32812 - Phone: (407) 855-9465 - Fax: (407) 826-0419

Client Name: UCF Storm Water Academy

Address:

Project Manager: Andrew Hood Phone:

Project Name: BAM Project Number:

Containers Accepted By: Cassie Pelto

Samples Collected By: Andrew Hood

						IDENTIFIER CODES											
								F	FP	P	SP	OG	M	FM	W		
						NUMBER OF SAMPLE BOTTLES COLLECTED											
								5		1							
Sample I.D.	*Matrix	**IPC	ERD Sample I.D. No.	Date Collected	Time Collected	1-Gallon Plastic (BP)	1-Liter Glass	60 mL Plastic (Filtered)	60 mL Plastic (Filtered/ Preserved w/ H_2SO_4)	60 mL Plastic (Preserved w/ H_2SO_4)	250 ml Plastic (SP)	Glass (Preserved w/ HCl)	Metals: 250 ml Plastic (Preserved w/ HNO_3) UF	F	Whirlpak	Other	Other
Column 4 A	SW	A	13-2424	7/2/13	1500			21									
Column 4 B	SW	A	2425	7/2/13	1500			21									
Column 4 C	SW	A	2426	7/2/13	1500			21									
Column 5 A	SW	A	2427	7/2/13	1500			20									
Column 5 B	SW	A	2428	7/2/13	1500			20									
Column 6 A	SW	A	2429	7/2/13	1500					22							
				DISPOSAL DATE:													

COMMENTS:

CUSTODY TRANSFERS			
Relinquished By	Received By	Date	Time
1. [illegible]	[illegible]	7/3/13	1348
2.			

Method of Shipment:

Delivered Directly to Lab: X

Shipped By FedEx: ___ UPS: ___ Other: ___

Received in Cooler: ✓ Y ___ N

Temperature: 4 °C

Shipped in Ice: ✓ Y ___ N

Ice Present: ✓ ___ Y ___ N

pH Checked in Laboratory (< 2 s.u.): ✓ Y ___ N

Chlorine Check (< 0.1 mg/l): ___ Y ✓ N

*MATRIX: SW=Stormwater SP=Seepage S=Surface Water BF=Baseflow GW=Groundwater BP=Bulk Precipitation G=Grab C=Composite

**ICE PRESERVATION CODES (IPC): A=Transported on ice, ice present when received B=Transported on ice, ice not present when received C=Not transported on ice

Page No ___

ENVIRONMENTAL RESEARCH & DESIGN, INC. ----- CHAIN-OF-CUSTODY RECORD

3419 Trentwood Blvd., Suite 102 - Orlando, FL 32812 - Phone: (407) 855-9465 - Fax: (407) 826-0419

Client Name: UCF Storm Water Academy

Address:

Project Manager: Andrew Hood   Phone:

Project Name: BAM   Project Number:

Containers Accepted By: Cassie Pelto

Samples Collected By: Andrew Hood

IDENTIFIER CODES / NUMBER OF SAMPLE BOTTLES COLLECTED

Sample I.D.	*Matrix	**IPC	ERD Sample I.D. No.	Date Collected	Time Collected	1-Gallon Plastic (BP)	1-Liter Glass	60 mL Plastic (Filtered)	60 mL Plastic (Filtered/ Preserved w/ H_2SO_4)	60 mL Plastic (Preserved w/ H_2SO_4)	250 ml Plastic (SP)	Glass (Preserved w/ HCl)	Metals: UF	Metals: 250 ml Plastic (Preserved w/ HNO_3) F	Whirlpak	Other ___	Other ___
Identifier code								F	FP	P	SP	OG	M	FM	W		
Number of bottles							10	10		11							
Column 1 A	SW	A	13-2413	7/2/13	1300		2,5	20,21		22,23,24							
Column 1 B	SW	A	2414	7/2/13	1300		2,5	20,21		22,23,24							
Column 1 C	SW	A	2415	7/2/13	1300		2,5	20,21		22,23,24							
Column 2 A	SW	A	2416	7/2/13	1300		2,5	20,21		22,23,24							
Column 2 B	SW	A	2417	7/2/13	1300		2,5	20,21		22,23,24							
Column 2 C	SW	A	2418	7/2/13	1300		2,5	20,21		22,23,24							
Column 3 A	SW	A	2419	7/2/13	1300		2,5	20,21		22,23,24							
Column 3 B	SW	A	2420	7/2/13	1300		2,5	20,21		22,23,24							
Column 3 C	SW	A	2421	7/2/13	1300		2,5	20,21		22,23,24							
Influent I	SW	A	2422	7/2/13	1300		2,5	20,21		22,23,24							
Influent II	SW	A	2423	7/2/13	1300					23							
DISPOSAL DATE:																	

COMMENTS:

CUSTODY TRANSFERS: Relinquished By	Received By	Date	Time
1. [signature]	[signature]	7/3/13	1348
2.			

Method of Shipment:
Delivered Directly to Lab: X
Shipped By FedEx: ___ UPS: ___ Other: ___

Received in Cooler: ✓ Y ___ N
Temperature: 4 °C
Shipped in Ice: ✓ Y ___ N
Ice Present: ✓ Y ___ N

pH Checked in Laboratory (< 2 s.u.): ✓ Y ___ N
Chlorine Check (< 0.1 mg/l): ___ Y ✓ N

*MATRIX: SW=Stormwater SP=Seepage S=Surface Water BF=Baseflow GW=Groundwater BP=Bulk Precipitation G=Grab C=Composite

**ICE PRESERVATION CODES (IPC): A=Transported on ice, ice present when received B=Transported on ice, ice not present when received C=Not transported on ice

Page No ____

ENVIRONMENTAL RESEARCH & DESIGN INC. ---- CHAIN-OF-CUSTODY RECORD

3419 Trentwood Blvd., Suite 102 - Orlando, FL 32812 - Phone: (407) 855-9465 - Fax: (407) 826-0419

Client Name: UCF Storm Water Academy

Address:

Project Manager: Andrew Hood   Phone:

Project Name: BAM   Project Number:

Containers Accepted By: Cassie Pelto

Samples Collected By: Andrew Hood

IDENTIFIER CODES / NUMBER OF SAMPLE BOTTLES COLLECTED

Sample I.D.	*Matrix	**IPC	ERD Sample I.D. No.	Date Collected	Time Collected	1-Gallon Plastic (BP)	1-Liter Glass	60 mL Plastic (Filtered)	60 mL Plastic (Filtered/ Preserved w/ H_2SO_4)	60 mL Plastic (Preserved w/ H_2SO_4)	250 ml Plastic (SP)	Glass (Preserved w/ HCl)	Metals: UF	250 ml Plastic (Preserved w/ HNO_3) F	Whirlpak	Other	Other
Identifier code								F	FP	P	SP	OG	M	FM	W		
Number of bottles							10	10		11							
Column 1 A	SW	A	13-2506	7/12/13	1100		2			23,24							
Column 1 B	SW	A	2507	7/12/13	1100		2			23,24							
Column 1 C	SW	A	2508	7/12/13	1100		2			23,24							
Column 2 A	SW	A	2509	7/12/13	1100		2			23,24							
Column 2 B	SW	A	2510	7/12/13	1100		2			23,24							
Column 2 C	SW	A	2511	7/12/13	1100		2			23,24							
Column 3 A	SW	A	2512	7/12/13	1100		2			23,24							
Column 3 B	SW	A	2513	7/12/13	1100		2			23,24							
Column 3 C	SW	A	2514	7/12/13	1100		2			23,24							
Influent I	SW	A	2515	7/12/13	1100		2			23,24							
Influent II	SW	A	2516	7/12/13	1100					23							
					DISPOSAL DATE:												

COMMENTS:

CUSTODY TRANSFERS Relinquished By	Received By	Date	Time
1. [signature]	[signature]	7/12/13	1515
2.			

Method of Shipment:

Delivered Directly to Lab: X

Shipped By FedEx: ____ UPS: ____ Other: ____

Received in Cooler: ✓ Y ___N

Temperature: 4 °C

Shipped in Ice: ✓ Y ___N

Ice Present: ✓ Y ___N

pH Checked in Laboratory (< 2 s.u.): ✓ Y ___N

Chlorine Check (< 0.1 mg/l): ___Y ✓ N

*MATRIX: SW=Stormwater SP=Seepage S=Surface Water BF=Baseflow GW=Groundwater BP=Bulk Precipitation G=Grab C=Composite

**ICE PRESERVATION CODES (IPC): A=Transported on ice, ice present when received B=Transported on ice, ice not present when received C=Not transported on ice

Page No.__

ENVIRONMENTAL RESEARCH & DESIGN, ;. ----- CHAIN-OF-CUSTODY RECORD

3419 Trentwood Blvd., Suite 102 - Orlando, FL 32812 - Phone: (407) 855-9465 - Fax: (407) 826-0419

Client Name: UCF Storm Water Academy

Address:

Project Manager: Andrew Hood Phone:

Project Name: BAM Project Number:

Containers Accepted By: Cassie Pelto

Samples Collected By: Andrew Hood

						IDENTIFIER CODES										
								F	FP	P	SP	OG	M	FM	W		
						NUMBER OF SAMPLE BOTTLES COLLECTED										
							10	~~10~~ Ø CP 8/2		11							
Sample I.D.	*Matrix	**IPC	ERD Sample I.D. No.	Date Collected	Time Collected	1- Gallon Plastic (BP)	1-Liter Glass	60 mL Plastic (Filtered)	60 mL Plastic (Filtered/ Preserved w/ H_2SO_4)	60 mL Plastic (Preserved w/ H_2SO_4)	250 ml Plastic (SP)	Glass (Preserved w/ HCl)	Metals: 250 ml Plastic (Preserved w/ HNO_3) UF	F	Whirlpak	Other	Other
Column 1 A	SW	A	13-2830	7/25/13	1300		2			23,24							
Column 1 B	SW	A	2831	7/25/13	1300		2			23,24							
Column 1 C	SW	A	2832	7/25/13	1300		2			23,24							
Column 2 A	SW	A	2833	7/25/13	1300		2			23,24							
Column 2 B	SW	A	2834	7/25/13	1300		2			23,24							
Column 2 C	SW	A	2835	7/25/13	1300		2			23,24							
Column 3 A	SW	A	2836	7/25/13	1300		2			23,24							
Column 3 B	SW	A	2837	7/25/13	1300		2			23,24							
Column 3 C	SW	A	2838	7/25/13	1300		2			23,24							
Influent I	SW	A	2839	7/25/13	1300		2			23,24							
Influent II	SW	A	2840	7/25/13	1300					23							
					DISPOSAL DATE:												

COMMENTS:

CUSTODY TRANSFERS			
Relinquished By	Received By	Date	Time
1. Andrew C. Hood	Cassie Pelto	8/2/13	1515
2.			

Method of Shipment:

Delivered Directly to Lab: _X__

Shipped By FedEx: _____ UPS: _____ Other: _____

Received in Cooler: ✓ Y __N

Temperature: 4 °C

Shipped in Ice: ✓ Y __N

Ice Present: ✓ Y __N

pH Checked in Laboratory (< 2 s.u.): ✓ Y __N

Chlorine Check (< 0.1 mg/l): __Y ✓ N

*MATRIX: SW=Stormwater SP=Seepage S=Surface Water BF=Baseflow GW=Groundwater BP=Bulk Precipitation G=Grab C=Composite

**ICE PRESERVATION CODES (IPC): A=Transported on ice, ice present when received B=Transported on ice, ice not present when received C=Not transported on ice

Page No.___

ENVIRONMENTAL RESEARCH & DESIGN, [illegible]. ----- CHAIN-OF-CUSTODY RECORD

3419 Trentwood Blvd., Suite 102 - Orlando, FL 32812 - Phone: (407) 855-9465 - Fax: (407) 826-0419

Client Name: UCF Storm Water Academy

Address:

Project Manager: Andrew Hood   Phone:

Project Name: BAM   Project Number:

Containers Accepted By: Cassie Pelto

Samples Collected By: Andrew Hood

IDENTIFIER CODES / NUMBER OF SAMPLE BOTTLES COLLECTED

Sample I.D.	*Matrix	**IPC	ERD Sample I.D. No.	Date Collected	Time Collected	1- Gallon Plastic (BP)	1-Liter Glass	60 mL Plastic (Filtered)	60 mL Plastic (Filtered/ Preserved w/ H_2SO_4)	60 mL Plastic (Preserved w/ H_2SO_4)	250 ml Plastic (SP)	Glass (Preserved w/ HCl)	Metals: UF	250 ml Plastic (Preserved w/ HNO_3) F	Whirlpak	Other ___	Other ___
Identifier codes								F	FP	P	SP	OG	M	FM	W		
Number of sample bottles collected										11							
Column 1 A	SW	A	13-2841	7/31/13	1300					23,24							
Column 1 B	SW	A	2842	7/31/13	1300					23,24							
Column 1 C	SW	A	2843	7/31/13	1300					23,24							
Column 2 A	SW	A	2844	7/31/13	1300					23,24							
Column 2 B	SW	A	2845	7/31/13	1300					23,24							
Column 2 C	SW	A	2846	7/31/13	1300					23,24							
Column 3 A	SW	A	2847	7/31/13	1300					23,24							
Column 3 B	SW	A	2848	7/31/13	1300					23,24							
Column 3 C	SW	A	2849	7/31/13	1300					23,24							
Influent I	SW	A	2850	7/31/13	1300					23,24							
Influent II	SW	A	2851	7/31/13	1300					23							
				DISPOSAL DATE:													

COMMENTS:

CUSTODY TRANSFERS

	Relinquished By	Received By	Date	Time
1.	[signature]	[signature]	8/2/13	1515
2.				

Method of Shipment:

Delivered Directly to Lab: X

Shipped By FedEx: ______ UPS: ______ Other: ______

Received in Cooler: ✓ Y ___N

Temperature: 4 °C

Shipped in Ice: ✓ Y ___N

Ice Present: ✓ Y ___N

pH Checked in Laboratory (< 2 s.u.): ✓ Y ___N

Chlorine Check (< 0.1 mg/l): ___Y ✓ N

*MATRIX: SW=Stormwater SP=Seepage S=Surface Water BF=Baseflow GW=Groundwater BP=Bulk Precipitation G=Grab C=Composite

**ICE PRESERVATION CODES (IPC): A=Transported on ice, ice present when received B=Transported on ice, ice not present when received C=Not transported on ice

Page No.__

ENVIRONMENTAL RESEARCH & DESIGN, ... ----- CHAIN-OF-CUSTODY RECORD

3419 Trentwood Blvd., Suite 102 - Orlando, FL 32812 - Phone: (407) 855-9465 - Fax: (407) 826-0419

Client Name: UCF Storm Water Academy

Address:

Project Manager: Andrew Hood Phone:

Project Name: BAM Project Number:

Containers Accepted By: Cassie Pelto

Samples Collected By: Andrew Hood

Sample I.D.	*Matrix	**IPC	ERD Sample I.D. No.	Date Collected	Time Collected	1- Gallon Plastic (BP)	1-Liter Glass	60 mL Plastic (Filtered)	60 mL Plastic (Filtered/ Preserved w/ H_2SO_4)	60 mL Plastic (Preserved w/ H_2SO_4)	250 ml Plastic (SP)	Glass (Preserved w/ HCl)	Metals: UF	250 ml Plastic (Preserved w/ HNO_3) F	Whirlpak	Other ___	Other ___
IDENTIFIER CODES								F	FP	P	SP	OG	M	FM	W		
NUMBER OF SAMPLE BOTTLES COLLECTED							10	~~10~~ 0 8/2		11							
Column 1 A	SW	A	132819	8/1/13	1300		2			23,24							
Column 1 B	SW	A	2820	8/1/13	1300		2			23,24							
Column 1 C	SW	A	2821	8/1/13	1300		2			23,24							
Column 2 A	SW	A	2822	8/1/13	1300		2			23,24							
Column 2 B	SW	A	2823	8/1/13	1300		2			23,24							
Column 2 C	SW	A	2824	8/1/13	1300		2			23,24							
Column 3 A	SW	A	2825	8/1/13	1300		2			23,24							
Column 3 B	SW	A	2826	8/1/13	1300		2			23,24							
Column 3 C	SW	A	2827	8/1/13	1300		2			23,24							
Influent I	SW	A	2828	8/1/13	1300		2			23,24							
Influent II	SW	A	2829	8/1/13	1300					23							
					DISPOSAL DATE:												

COMMENTS:

CUSTODY TRANSFERS

Relinquished By	Received By	Date	Time
1. Andrew C. Hood	Cassie Pelto	8/2/13	1515
2.			

Method of Shipment:

Delivered Directly to Lab: X

Shipped By FedEx: ___ UPS: ___ Other: ___

Received in Cooler: ✓ Y ___ N

Temperature: 4 °C

Shipped in Ice: ✓ Y ___ N

Ice Present: ✓ Y ___ N

pH Checked in Laboratory (< 2 s.u.): ✓ Y ___ N

Chlorine Check (< 0.1 mg/l): ___ Y ✓ N

*MATRIX: SW=Stormwater SP=Seepage S=Surface Water BF=Baseflow GW=Groundwater BP=Bulk Precipitation G=Grab C=Composite

**ICE PRESERVATION CODES (IPC): A=Transported on ice, ice present when received B=Transported on ice, ice not present when received C=Not transported on ice

Page No. ___

ENVIRONMENTAL RESEARCH & DESIGN, INC. ----- CHAIN-OF-CUSTODY RECORD

3419 Trentwood Blvd., Suite 102 - Orlando, FL 32812 - Phone: (407) 855-9465 - Fax: (407) 826-0419

Client Name: UCF Storm Water Academy

Address:

Project Manager: Andrew Hood   Phone:

Project Name: BAM   Project Number:

Containers Accepted By: Cassie Pelto

Samples Collected By: Andrew Hood

IDENTIFIER CODES / NUMBER OF SAMPLE BOTTLES COLLECTED

Sample I.D.	*Matrix	**IPC	ERD Sample I.D. No.	Date Collected	Time Collected	1-Gallon Plastic (BP)	1-Liter Glass	F: 60 mL Plastic (Filtered)	FP: 60 mL Plastic (Filtered/ Preserved w/ H_2SO_4)	P: 60 mL Plastic (Preserved w/ H_2SO_4)	SP: 250 ml Plastic (SP)	OG: Glass (Preserved w/ HCl)	M: Metals: 250 ml Plastic (Preserved w/ HNO_3) UF	FM: F	W: Whirlpak	Other	Other
							10			11							
Column 1 A	SW	A	B-2995	8/7/13	1300		2			23,24							
Column 1 B	SW	A	2996	8/7/13	1300		2			23,24							
Column 1 C	SW	A	2997	8/7/13	1300		2			23,24							
Column 2 A	SW	A	2998	8/7/13	1300		2			23,24							
Column 2 B	SW	A	2999	8/7/13	1300		2			23,24							
Column 2 C	SW	A	3000	8/7/13	1300		2			23,24							
Column 3 A	SW	A	3001	8/7/13	1300		2			23,24							
Column 3 B	SW	A	3002	8/7/13	1300		2			23,24							
Column 3 C	SW	A	3003	8/7/13	1300		2			23,24							
Influent I	SW	A	3004	8/7/13	1300		2			23,24							
Influent II	SW	A	3005	8/7/13	1300					23							
				DISPOSAL DATE:													

COMMENTS:

CUSTODY TRANSFERS: Relinquished By	Received By	Date	Time
1. Andrew Hood	Cassie Pelto	8/16/13	1415
2.			

Method of Shipment:

Delivered Directly to Lab: X

Shipped By FedEx: ____ UPS: ____ Other: ____

Received in Cooler: ✓ Y ___ N

Temperature: 4 °C

Shipped in Ice: ✓ Y ___ N

Ice Present: ✓ Y ___ N

pH Checked in Laboratory (< 2 s.u.): ✓ Y ___ N

Chlorine Check (< 0.1 mg/l): ___ Y ✓ N

*MATRIX: SW=Stormwater SP=Seepage S=Surface Water BF=Baseflow GW=Groundwater BP=Bulk Precipitation G=Grab C=Composite

**ICE PRESERVATION CODES (IPC): A=Transported on ice, ice present when received B=Transported on ice, ice not present when received C=Not transported on ice

Page No ___

ENVIRONMENTAL RESEARCH & DESIGN, INC. ----- CHAIN-OF-CUSTODY RECORD

3419 Trentwood Blvd., Suite 102 - Orlando, FL 32812 - Phone: (407) 855-9465 - Fax: (407) 826-0419

Client Name: UCF Storm Water Academy

Address:

Project Manager: Andrew Hood Phone:

Project Name: BAM Project Number:

Containers Accepted By: Cassie Pelto

Samples Collected By: Andrew Hood

						IDENTIFIER CODES											
								F	FP	P	SP	OG	M	FM	W		
						NUMBER OF SAMPLE BOTTLES COLLECTED											
							10			11							
Sample I.D.	*Matrix	**IPC	ERD Sample I.D. No.	Date Collected	Time Collected	1- Gallon Plastic (BP)	1-Liter Glass	60 mL Plastic (Filtered)	60 mL Plastic (Filtered/ Preserved w/ H_2SO_4)	60 mL Plastic (Preserved w/ H_2SO_4)	250 ml Plastic (SP)	Glass (Preserved w/ HCl)	Metals: 250 ml Plastic (Preserved w/ HNO_3) UF	F	Whirlpak	Other ___	Other ___
Column 1 A	SW	A	13-2984	8/5/13	1300		2			23,24							
Column 1 B	SW	A	2985	8/5/13	1300		2			23,24							
Column 1 C	SW	A	2986	8/5/13	1300		2			23,24							
Column 2 A	SW	A	2987	8/5/13	1300		2			23,24							
Column 2 B	SW	A	2988	8/5/13	1300		2			23,24							
Column 2 C	SW	A	2989	8/5/13	1300		2			23,24							
Column 3 A	SW	A	2990	8/5/13	1300		2			23,24							
Column 3 B	SW	A	2991	8/5/13	1300		2			23,24							
Column 3 C	SW	A	2992	8/5/13	1300		2			23,24							
Influent I	SW	A	2993	8/5/13	1300		2			23,24							
Influent II	SW	A	2994	8/5/13	1300					23							
				DISPOSAL DATE:													

COMMENTS:

CUSTODY TRANSFERS			
Relinquished By	Received By	Date	Time
1. Andrew C. Hood	Cassie Pelto	8/16/13	1415
2.			

Method of Shipment:

Delivered Directly to Lab: X

Shipped By FedEx: ___ UPS: ___ Other: ___

Received in Cooler: ✓ Y ___ N

Temperature: 4 °C

Shipped in Ice: ✓ Y ___ N

Ice Present: ✓ Y ___ N

pH Checked in Laboratory (< 2 s.u.): ✓ Y ___ N

Chlorine Check (< 0.1 mg/l): ___ Y ✓ N

*MATRIX: SW=Stormwater SP=Seepage S=Surface Water BF=Baseflow GW=Groundwater BP=Bulk Precipitation G=Grab C=Composite

**ICE PRESERVATION CODES (IPC): A=Transported on ice, ice present when received B=Transported on ice, ice not present when received C=Not transported on ice

Page No ___

ENVIRONMENTAL RESEARCH & DESIGN, INC. ----- CHAIN-OF-CUSTODY RECORD

3419 Trentwood Blvd., Suite 102 - Orlando, FL 32812 - Phone: (407) 855-9465 - Fax: (407) 826-0419

Client Name: UCF Storm Water Academy

Address:

Project Manager: Andrew Hood Phone:

Project Name: BAM Project Number:

Containers Accepted By: Cassie Pelto

Samples Collected By: Andrew Hood

Sample I.D.	*Matrix	**IPC	ERD Sample I.D. No.	Date Collected	Time Collected	1-Gallon Plastic (BP)	1-Liter Glass	60 mL Plastic (Filtered)	60 mL Plastic (Filtered/ Preserved w/ H_2SO_4)	60 mL Plastic (Preserved w/ H_2SO_4)	250 ml Plastic (SP)	Glass (Preserved w/ HCl)	Metals: 250 ml Plastic (Preserved w/ HNO_3) UF	Metals: 250 ml Plastic (Preserved w/ HNO_3) F	Whirlpak	Other ___	Other ___
IDENTIFIER CODES								F	FP	P	SP	OG	M	FM	W		
NUMBER OF SAMPLE BOTTLES COLLECTED							10			11							
Column 1 A	SW	A	13-3006	8/13/13	1300		2			23,24							
Column 1 B	SW	A	3007	8/13/13	1300		2			23,24							
Column 1 C	SW	A	3008	8/13/13	1300		2			23,24							
Column 2 A	SW	A	3009	8/13/13	1300		2			23,24							
Column 2 B	SW	A	3010	8/13/13	1300		2			23,24							
Column 2 C	SW	A	3011	8/13/13	1300		2			23,24							
Column 3 A	SW	A	3012	8/13/13	1300		2			23,24							
Column 3 B	SW	A	3013	8/13/13	1300		2			23,24							
Column 3 C	SW	A	3014	8/13/13	1300		2			23,24							
Influent I	SW	A	3015	8/13/13	1300		2			23,24							
Influent II	SW	A	3016	8/13/13	1300					23							
					DISPOSAL DATE:												

COMMENTS:

CUSTODY TRANSFERS			
Relinquished By	Received By	Date	Time
1. Andrew Hood	Cassie Pelto	8/16/13	1415
2.			

Method of Shipment:

Delivered Directly to Lab: X

Shipped By FedEx: ______
UPS: ______
Other: ______

Received in Cooler: ✓ Y ___ N

Temperature: 4 °C

Shipped in Ice: ✓ Y ___ N

Ice Present: ✓ Y ___ N

pH Checked in Laboratory (< 2 s.u.): ✓ Y ___ N

Chlorine Check (< 0.1 mg/l): ___ Y ✓ N

*MATRIX: SW=Stormwater SP=Seepage S=Surface Water BF=Baseflow GW=Groundwater BP=Bulk Precipitation G=Grab C=Composite

**ICE PRESERVATION CODES (IPC): A=Transported on ice, ice present when received B=Transported on ice, ice not present when received C=Not transported on ice

Page No ___

ENVIRONMENTAL RESEARCH & DESIGN, INC. ----- CHAIN-OF-CUSTODY RECORD

3419 Trentwood Blvd., Suite 102 - Orlando, FL 32812 - Phone: (407) 855-9465 - Fax: (407) 826-0419

Client Name: UCF Storm Water Academy

Address:

Project Manager: Andrew Hood Phone:

Project Name: BAM Project Number:

Containers Accepted By: Cassie Pelto

Samples Collected By: Andrew Hood

Sample I.D.	*Matrix	**IPC	8/19 GP ERD Sample I.D. No.	Date Collected	Time Collected	1- Gallon Plastic (BP)	1-Liter Glass	60 mL Plastic (Filtered)	60 mL Plastic (Filtered/ Preserved w/ H_2SO_4)	60 mL Plastic (Preserved w/ H_2SO_4)	250 ml Plastic (SP)	Glass (Preserved w/ HCl)	Metals: UF	Metals: 250 ml Plastic (Preserved w/ HNO_3) F	Whirlpak	Other ___	Other ___
IDENTIFIER CODES								F	FP	P	SP	OG	M	FM	W		
NUMBER OF SAMPLE BOTTLES COLLECTED							10			11							
Column 1 A	SW	A	13-~~2984~~ 3017	8/15/13	1300		2			23,24							
Column 1 B	SW	A	3018	8/15/13	1300		2			23,24							
Column 1 C	SW	A	3019	8/15/13	1300		2			23,24							
Column 2 A	SW	A	3020	8/15/13	1300		2			23,24							
Column 2 B	SW	A	3021	8/15/13	1300		2			23,24							
Column 2 C	SW	A	3022	8/15/13	1300		2			23,24							
Column 3 A	SW	A	3023	8/15/13	1300		2			23,24							
Column 3 B	SW	A	3024	8/15/13	1300		2			23,24							
Column 3 C	SW	A	3025	8/15/13	1300		2			23,24							
Influent I	SW	A	3026	8/15/13	1300		2			23,24							
Influent II	SW	A	3027	8/15/13	1300					23							
				DISPOSAL DATE:													

COMMENTS:

CUSTODY TRANSFERS

Relinquished By	Received By	Date	Time
1. Andrew C. Hood	Cassie Pelto	8/16/13	1415
2.			

Method of Shipment:

Delivered Directly to Lab: X

Shipped By FedEx: ______ UPS: ______ Other: ______

Received in Cooler: ✓ Y ___ N

Temperature: 4 °C

Shipped in Ice: ✓ Y ___ N

Ice Present: ✓ Y ___ N

pH Checked in Laboratory (< 2 s.u.): ✓ Y ___ N

Chlorine Check (< 0.1 mg/l): ___ Y ✓ N

*MATRIX: SW=Stormwater SP=Seepage S=Surface Water BF=Baseflow GW=Groundwater BP=Bulk Precipitation G=Grab C=Composite

**ICE PRESERVATION CODES (IPC): A=Transported on ice, ice present when received B=Transported on ice, ice not present when received C=Not transported on ice

Page No ___

ENVIRONMENTAL RESEARCH & DESIG INC. ----- CHAIN-OF-CUSTODY RECORD

3419 Trentwood Blvd., Suite 102 - Orlando, FL 32812 - Phone: (407) 855-9465 - Fax: (407) 826-0419

Client Name: UCF Storm Water Academy

Address:

Project Manager: Andrew Hood Phone:

Project Name: BAM Project Number:

Containers Accepted By: Cassie Pelto

Samples Collected By: Andrew Hood

IDENTIFIER CODES / NUMBER OF SAMPLE BOTTLES COLLECTED

Sample I.D.	*Matrix	**IPC	ERD Sample I.D. No.	Date Collected	Time Collected	1- Gallon Plastic (BP)	1-Liter Glass	60 mL Plastic (Filtered)	60 mL Plastic (Filtered/ Preserved w/ H_2SO_4)	60 mL Plastic (Preserved w/ H_2SO_4)	250 ml Plastic (SP)	Glass (Preserved w/ HCl)	Metals: UF	250 ml Plastic (Preserved w/ HNO_3) F	Whirlpak	Other	Other
								F	FP	P	SP	OG	M	FM	W		
							10			11							
Column 1 A	SW	A	13-3145	8/27/13	1300		2			23,24							
Column 1 B	SW	A	3146	8/27/13	1300		2			23,24							
Column 1 C	SW	A	3147	8/27/13	1300		2			23,24							
Column 2 A	SW	A	3148	8/27/13	1300		2			23,24							
Column 2 B	SW	A	3149	8/27/13	1300		2			23,24							
Column 2 C	SW	A	3150	8/27/13	1300		2			23,24							
Column 3 A	SW	A	3151	8/27/13	1300		2			23,24							
Column 3 B	SW	A	3152	8/27/13	1300		2			23,24							
Column 3 C	SW	A	3153	8/27/13	1300		2			23,24							
Influent I	SW	A	3154	8/27/13	1300		2			23,24							
Influent II	SW	A	3155	8/27/13	1300					23							
				DISPOSAL DATE:													

COMMENTS:

CUSTODY TRANSFERS			
Relinquished By	Received By	Date	Time
1. [signature]	[signature]	8/29/13	~~1415~~ am 8:29 13:15
2.			

Method of Shipment:

Delivered Directly to Lab: X

Shipped By FedEx: ___ UPS: ___ Other: ___

Received in Cooler: ✓ Y ___ N

Temperature: 4 °C

Shipped in Ice: ✓ Y ___ N

Ice Present: ✓ Y ___ N

pH Checked in Laboratory (< 2 s.u.): ✓ Y ___ N

Chlorine Check (< 0.1 mg/l): ___ Y ✓ N

*MATRIX: SW=Stormwater SP=Seepage S=Surface Water BF=Baseflow GW=Groundwater BP=Bulk Precipitation G=Grab C=Composite

**ICE PRESERVATION CODES (IPC): A=Transported on ice, ice present when received B=Transported on ice, ice not present when received C=Not transported on ice

Page No ___

ENVIRONMENTAL RESEARCH & DESIG. INC. ----- CHAIN-OF-CUSTODY RECORD

3419 Trentwood Blvd., Suite 102 - Orlando, FL 32812 - Phone: (407) 855-9465 - Fax: (407) 826-0419

Client Name: UCF Storm Water Academy

Address:

Project Manager: Andrew Hood Phone:

Project Name: BAM Project Number:

Containers Accepted By: Cassie Pelto

Samples Collected By: Andrew Hood

IDENTIFIER CODES / NUMBER OF SAMPLE BOTTLES COLLECTED

Sample I.D.	*Matrix	**IPC	ERD Sample I.D. No.	Date Collected	Time Collected	1- Gallon Plastic (BP)	1-Liter Glass	F: 60 mL Plastic (Filtered)	FP: 60 mL Plastic (Filtered/ Preserved w/ H_2SO_4)	P: 60 mL Plastic (Preserved w/ H_2SO_4)	SP: 250 ml Plastic (SP)	OG: Glass (Preserved w/ HCl)	M: Metals: 250 ml Plastic (Preserved w/ HNO_3) UF	FM: F	W: Whirlpak	Other ___	Other ___
							~~10~~ 8			11							
Column 1 A	SW	A	13-3344	8/29/13	1300		2			22,23,24							
Column 1 B	SW	A	3345	8/29/13	1300		2			22,23,24							
Column 1 C	SW	A	3346	8/29/13	1300		2			22,23,24							
Column 2 A	SW	A	3347	8/29/13	1300		2			22,23,24							
Column 2 B	SW	A	3348	8/29/13	1300		2			22,23,24							
Column 2 C	SW	A	3349	8/29/13	1300		2			22,23,24							
Column 3 A	SW	A	3350	8/29/13	1300		2			22,23,24							
Column 3 B	SW	A	3351	8/29/13	1300		2			22,23,24							
Column 3 C	SW	A	3352	8/29/13	1300		2			22,23,24							
Influent I	SW	A	3353	8/29/13	1300		2			22,23,24							
Influent II	SW	A	13-3354	8/29/13	1300					22, 23, 24							
DISPOSAL DATE:																	

COMMENTS:

CUSTODY TRANSFERS

Relinquished By	Received By	Date	Time
1.	S Darling	9/16/13	1615
2.			

Method of Shipment:

Delivered Directly to Lab: X

Shipped By FedEx: ____ UPS: ____ Other: ____

Received in Cooler: ___Y ___N

Temperature: ______°C

Shipped in Ice: ___Y ___N

Ice Present: ___Y ___N

pH Checked in Laboratory (< 2 s.u.): ___Y ___N

Chlorine Check (< 0.1 mg/l): ___Y ___N

*MATRIX: SW=Stormwater SP=Seepage S=Surface Water BF=Baseflow GW=Groundwater BP=Bulk Precipitation G=Grab C=Composite

**ICE PRESERVATION CODES (IPC): A=Transported on ice, ice present when received B=Transported on ice, ice not present when received C=Not transported on ice

Page No ___

ENVIRONMENTAL RESEARCH & DESIG INC. ---- CHAIN-OF-CUSTODY RECORD

3419 Trentwood Blvd., Suite 102 - Orlando, FL 32812 - Phone: (407) 855-9465 - Fax: (407) 826-0419

Client Name: UCF Storm Water Academy	
Address:	
Project Manager: Andrew Hood	Phone:
Project Name: BAM	Project Number:
Containers Accepted By: Cassie Pelto	
Samples Collected By: Andrew Hood	

IDENTIFIER CODES / **NUMBER OF SAMPLE BOTTLES COLLECTED**

Sample I.D.	*Matrix	**IPC	ERD Sample I.D. No.	Date Collected	Time Collected	1- Gallon Plastic (BP)	1-Liter Glass	F: 60 mL Plastic (Filtered)	FP: 60 mL Plastic (Filtered/ Preserved w/ H_2SO_4)	P: 60 mL Plastic (Preserved w/ H_2SO_4)	SP: 250 ml Plastic (SP)	OG: Glass (Preserved w/ HCl)	M: Metals: 250 ml Plastic (Preserved w/ HNO_3) UF	FM: F	W: Whirlpak	Other	Other
							~~10~~ ~~Ø~~			11							
Column 1 A	SW	A	13-3355	9/3/13	1300		2			22,23,24							
Column 1 B	SW	A	3356	9/3/13	1300		2			22,23,24							
Column 1 C	SW	A	3357	9/3/13	1300		2			22,23,24							
Column 2 A	SW	A	3358	9/3/13	1300		2			22,23,24							
Column 2 B	SW	A	3359	9/3/13	1300		2			22,23,24							
Column 2 C	SW	A	3360	9/3/13	1300		2			22,23,24							
Column 3 A	SW	A	3361	9/3/13	1300		2			22,23,24							
Column 3 B	SW	A	3362	9/3/13	1300		2			22,23,24							
Column 3 C	SW	A	3363	9/3/13	1300		2			22,23,24							
Influent I	SW	A	3364	9/3/13	1300		2			22,23,24							
Influent II	SW	A	13-3365	9/3/13	1300					22, 23, 24							
DISPOSAL DATE:																	

COMMENTS:

CUSTODY TRANSFERS

Relinquished By	Received By	Date	Time
1.	SDarling	9/16/13	1615
2.			

Method of Shipment:		
Delivered Directly to Lab: X	Received in Cooler: ___Y ___N	pH Checked in Laboratory (< 2 s.u.): ___Y ___N
Shipped By FedEx: ____ UPS: ____ Other: ____	Temperature: ______ °C	Chlorine Check (< 0.1 mg/l): ___Y ___N
	Shipped in Ice: ___Y ___N	
	Ice Present: ___Y ___N	

*MATRIX: SW=Stormwater SP=Seepage S=Surface Water BF=Baseflow GW=Groundwater BP=Bulk Precipitation G=Grab C=Composite

**ICE PRESERVATION CODES (IPC): A=Transported on ice, ice present when received B=Transported on ice, ice not present when received C=Not transported on ice

Page No. ___

ENVIRONMENTAL RESEARCH & DESIGN, INC. ----- CHAIN-OF-CUSTODY RECORD

3419 Trentwood Blvd., Suite 102 - Orlando, FL 32812 - Phone: (407) 855-9465 - Fax: (407) 826-0419

Client Name: UCF Storm Water Academy

Address:

Project Manager: | Phone:

Project Name: BAM | Project Number:

Containers Accepted By: Cassie Pelto

Samples Collected By: Andrew Hood

IDENTIFIER CODES / NUMBER OF SAMPLE BOTTLES COLLECTED

Sample I.D.	*Matrix	**IPC	ERD Sample I.D. No.	Date Collected	Time Collected	1- Gallon Plastic (BP)	1-Liter Glass	F: 60 mL Plastic (Filtered)	FP: 60 mL Plastic (Filtered/ Preserved w/ H_2SO_4)	P: 60 mL Plastic (Preserved w/ H_2SO_4)	SP: 250 ml Plastic (SP)	OG: Glass (Preserved w/ HCl)	M: Metals: 250 ml Plastic (Preserved w/ HNO_3) UF	FM: F	W: Whirlpak	Other	Other
							10	11		11							
Column 1 A	SW	A	13-3513	9/24/13	1300		2	20,21		22,23,24							
Column 1 B	SW	A	3514	9/24/13	1300		2	20,21		22,23,24							
Column 1 C	SW	A	3515	9/24/13	1300		2	20,21		22,23,24							
Column 2 A	SW	A	3516	9/24/13	1300		2	20,21		22,23,24							
Column 2 B	SW	A	3517	9/24/13	1300		2	20,21		22,23,24							
Column 2 C	SW	A	3518	9/24/13	1300		2	20,21		22,23,24							
Column 3 A	SW	A	3519	9/24/13	1300		2	20,21		22,23,24							
Column 3 B	SW	A	3520	9/24/13	1300		2	20,21		22,23,24							
Column 3 C	SW	A	3521	9/24/13	1300		2	20,21		22,23,24							
Influent I	SW	A	3522	9/24/13	1300		2	20,21		22,23,24							
Influent II	SW	A	3523	9/24/13	1300			20,21		22,23,24							
					DISPOSAL DATE:												

COMMENTS:

CUSTODY TRANSFERS

	Relinquished By	Received By	Date	Time
1.	[signature]	[signature]	9/25/13	1515
2.		[signature]		

Method of Shipment:

Delivered Directly to Lab: X

Shipped By FedEx: ______ UPS: ______ Other: ______

Received in Cooler: ✓ Y ___ N

Temperature: 4 °C

Shipped in Ice: ✓ Y ___ N

Ice Present: ✓ Y ___ N

pH Checked in Laboratory (< 2 s.u.): ✓ Y ___ N

Chlorine Check (< 0.1 mg/l): ___ Y ✓ N

*MATRIX: SW=Stormwater SP=Seepage S=Surface Water BF=Baseflow GW=Groundwater BP=Bulk Precipitation G=Grab C=Composite

**ICE PRESERVATION CODES (IPC): A=Transported on ice, ice present when received B=Transported on ice, ice not present when received C=Not transported on ice

Page No. __

ENVIRONMENTAL RESEARCH & DESIGN, INC. ----- CHAIN-OF-CUSTODY RECORD

3419 Trentwood Blvd., Suite 102 - Orlando, FL 32812 - Phone: (407) 855-9465 - Fax: (407) 826-0419

Client Name: UCF Storm Water Academy

Address:

Project Manager: Phone:

Project Name: BAM Project Number:

Containers Accepted By: Cassie Pelto

Samples Collected By: Andrew Hood

IDENTIFIER CODES / NUMBER OF SAMPLE BOTTLES COLLECTED

Sample I.D.	*Matrix	**IPC	ERD Sample I.D. No.	Date Collected	Time Collected	1- Gallon Plastic (BP)	1-Liter Glass	60 mL Plastic (Filtered)	60 mL Plastic (Filtered/ Preserved w/ H_2SO_4)	60 mL Plastic (Preserved w/ H_2SO_4)	250 ml Plastic (SP)	Glass (Preserved w/ HCl)	Metals: 250 ml Plastic (Preserved w/ HNO_3) UF	Metals: 250 ml Plastic (Preserved w/ HNO_3) F	Whirlpak	Other ___	Other ___
Identifier codes								F	FP	P	SP	OG	M	FM	W		
Number of bottles							10	11		11							
Column 1 A	SW	A	B-3559	9/27/13	1300		2	20,21		22,23,24							
Column 1 B	SW	A	3560	9/27/13	1300		2	20,21		22,23,24							
Column 1 C	SW	A	3561	9/27/13	1300		2	20,21		22,23,24							
Column 2 A	SW	A	3562	9/27/13	1300		2	20,21		22,23,24							
Column 2 B	SW	A	3563	9/27/13	1300		2	20,21		22,23,24							
Column 2 C	SW	A	3564	9/27/13	1300		2	20,21		22,23,24							
Column 3 A	SW	A	3565	9/27/13	1300		2	20,21		22,23,24							
Column 3 B	SW	A	3566	9/27/13	1300		2	20,21		22,23,24							
Column 3 C	SW	A	3567	9/27/13	1300		2	20,21		22,23,24							
Influent I	SW	A	3568	9/27/13	1300		2	20,21		22,23,24							
Influent II	SW	A	3569	9/27/13	1300			20,21		22,23,24							
				DISPOSAL DATE:													

COMMENTS:

CUSTODY TRANSFERS

Relinquished By	Received By	Date	Time
1. [signature]	[signature]	9/27/13	1321
2.			

Method of Shipment:

Delivered Directly to Lab: X

Shipped By FedEx: ___ UPS: ___ Other: ___

Received in Cooler: ___Y ___N

Temperature: ___ °C

Shipped in Ice: ___Y ___N

Ice Present: ___Y ___N

pH Checked in Laboratory (< 2 s.u.): ___Y ___N

Chlorine Check (< 0.1 mg/l): ___Y ___N

*MATRIX: SW=Stormwater SP=Seepage S=Surface Water BF=Baseflow GW=Groundwater BP=Bulk Precipitation G=Grab C=Composite

**ICE PRESERVATION CODES (IPC): A=Transported on ice, ice present when received B=Transported on ice, ice not present when received C=Not transported on ice

Page No.

ENVIRONMENTAL RESEARCH & DESIGN, INC. ----- CHAIN-OF-CUSTODY RECORD

3419 Trentwood Blvd., Suite 102 - Orlando, FL 32812 - Phone: (407) 855-9465 - Fax: (407) 826-0419

Client Name: UCF Storm Water Academy

Address:

Project Manager: Phone:

Project Name: BAM Project Number:

Containers Accepted By: Cassie Pelto

Samples Collected By: Andrew Hood

						IDENTIFIER CODES											
								F	FP	P	SP	OG	M	FM	W		
						NUMBER OF SAMPLE BOTTLES COLLECTED											
							10	11		11							
Sample I.D.	*Matrix	**IPC	ERD Sample I.D. No.	Date Collected	Time Collected	1-Gallon Plastic (BP)	1-Liter Glass	60 mL Plastic (Filtered)	60 mL Plastic (Filtered/ Preserved w/ H_2SO_4)	60 mL Plastic (Preserved w/ H_2SO_4)	250 ml Plastic (SP)	Glass (Preserved w/ HCl)	Metals: 250 ml Plastic (Preserved w/ HNO_3) UF	F	Whirlpak	Other	Other
Column 1 A	SW	A	13-3647	10/4/13	1030		2	20,21		22,23,24							
Column 1 B	SW	A	3648	10/4/13	1030		2	20,21		22,23,24							
Column 1 C	SW	A	3649	10/4/13	1030		2	20,21		22,23,24							
Column 2 A	SW	A	3650	10/4/13	1030		2	20,21		22,23,24							
Column 2 B	SW	A	3651	10/4/13	1030		2	20,21		22,23,24							
Column 2 C	SW	A	3652	10/4/13	1030		2	20,21		22,23,24							
Column 3 A	SW	A	3653	10/4/13	1030		2	20,21		22,23,24							
Column 3 B	SW	A	3654	10/4/13	1030		2	20,21		22,23,24							
Column 3 C	SW	A	3655	10/4/13	1030		2	20,21		22,23,24							
Influent I	SW	A	3656	10/4/13	1030		2	20,21		22,23,24							
Influent II	SW	A	3657	10/4/13	1030			20,21		22,23,24							
				DISPOSAL DATE:													

COMMENTS:

CUSTODY TRANSFERS			
Relinquished By	Received By	Date	Time
1. Michael Acebo	Cassie Pelto	10/4/13	1315
2.			

Method of Shipment:

Delivered Directly to Lab: X

Shipped By FedEx: ____ UPS: ____ Other: ____

Received in Cooler: ✓ Y ___ N

Temperature: 4 °C

Shipped in Ice: ✓ Y ___ N

Ice Present: ✓ Y ___ N

pH Checked in Laboratory (< 2 s.u.): ___ Y ___ N

Chlorine Check (< 0.1 mg/l): ___ Y ✓ N

*MATRIX: SW=Stormwater SP=Seepage S=Surface Water BF=Baseflow GW=Groundwater BP=Bulk Precipitation G=Grab C=Composite

**ICE PRESERVATION CODES (IPC): A=Transported on ice, ice present when received B=Transported on ice, ice not present when received C=Not transported on ice

Page No ___

ENVIRONMENTAL RESEARCH & DESIG INC. ----- CHAIN-OF-CUSTODY RECORD

3419 Trentwood Blvd., Suite 102 - Orlando, FL 32812 - Phone: (407) 855-9465 - Fax: (407) 826-0419

Client Name: UCF Storm Water Academy

Address:

Project Manager: Phone:

Project Name: BAM Project Number:

Containers Accepted By: Cassie Pelto

Samples Collected By: Andrew Hood

IDENTIFIER CODES / NUMBER OF SAMPLE BOTTLES COLLECTED

Identifier code			F	FP	P	SP	OG	M	FM	W		
Number of sample bottles collected		10	11		11							
Container	1- Gallon Plastic (BP)	1-Liter Glass	60 mL Plastic (Filtered)	60 mL Plastic (Filtered/ Preserved w/ H_2SO_4)	60 mL Plastic (Preserved w/ H_2SO_4)	250 ml Plastic (SP)	Glass (Preserved w/ HCl)	Metals: 250 ml Plastic (Preserved w/ HNO_3) UF	F	Whirlpak	Other ___	Other ___

Sample I.D.	*Matrix	**IPC	ERD Sample I.D. No.	Date Collected	Time Collected	1- Gallon Plastic (BP)	1-Liter Glass	60 mL Plastic (Filtered)	60 mL Plastic (Filtered/ Preserved w/ H_2SO_4)	60 mL Plastic (Preserved w/ H_2SO_4)	250 ml Plastic (SP)	Glass (Preserved w/ HCl)	Metals UF	Metals F	Whirlpak	Other	Other
Column 1 A	SW	A	13-3721	10/8/13	1300		2	20,21		22,23,24							
Column 1 B	SW	A	3722	10/8/13	1300		2	20,21		22,23,24							
Column 1 C	SW	A	3723	10/8/13	1300		2	20,21		22,23,24							
Column 2 A	SW	A	3724	10/8/13	1300		2	20,21		22,23,24							
Column 2 B	SW	A	3725	10/8/13	1300		2	20,21		22,23,24							
Column 2 C	SW	A	3726	10/8/13	1300		2	20,21		22,23,24							
Column 3 A	SW	A	3727	10/8/13	1300		2	20,21		22,23,24							
Column 3 B	SW	A	3728	10/8/13	1300		2	20,21		22,23,24							
Column 3 C	SW	A	3729	10/8/13	1300		2	20,21		22,23,24							
Influent I	SW	A	3730	10/8/13	1300		2	20,21		22,23,24							
Influent II	SW	A	3731	10/8/13	1300			20,21		22,23,24							
					DISPOSAL DATE:												

COMMENTS:

CUSTODY TRANSFERS

Relinquished By	Received By	Date	Time
1. ACH	Cassie Pelto	10/9/13	1600
2.			

Method of Shipment:

Delivered Directly to Lab: X

Shipped By FedEx: ___ UPS: ___ Other: ___

Received in Cooler: ✓ Y ___ N

Temperature: 4 °C

Shipped in Ice: ✓ Y ___ N

Ice Present: ✓ Y ___ N

pH Checked in Laboratory (< 2 s.u.): ✓ Y ___ N

Chlorine Check (< 0.1 mg/l): ___ Y ✓ N

*MATRIX: SW=Stormwater SP=Seepage S=Surface Water BF=Baseflow GW=Groundwater BP=Bulk Precipitation G=Grab C=Composite

**ICE PRESERVATION CODES (IPC): A=Transported on ice, ice present when received B=Transported on ice, ice not present when received C=Not transported on ice

Page No._

ENVIRONMENTAL RESEARCH & DESIGN, INC. ----- CHAIN-OF-CUSTODY RECORD

3419 Trentwood Blvd., Suite 102 - Orlando, FL 32812 - Phone: (407) 855-9465 - Fax: (407) 826-0419

Client Name: UCF Storm Water Academy

Address:

Project Manager: Phone:

Project Name: BAM Project Number:

Containers Accepted By: Cassie Pelto

Samples Collected By: Andrew Hood

Sample I.D.	*Matrix	**IPC	ERD Sample I.D. No.	Date Collected	Time Collected	1- Gallon Plastic (BP)	1-Liter Glass	60 mL Plastic (Filtered)	60 mL Plastic (Filtered/ Preserved w/ H_2SO_4)	60 mL Plastic (Preserved w/ H_2SO_4)	250 ml Plastic (SP)	Glass (Preserved w/ HCl)	Metals: 250 ml Plastic (Preserved w/ HNO_3) UF	Metals: 250 ml Plastic (Preserved w/ HNO_3) F	Whirlpak	Other	Other
Identifier Codes								F	FP	P	SP	OG	M	FM	W		
Number of Sample Bottles Collected							10	11		11							
Column 1 A	SW	A	13-3788	10/16/13	1200		2	20,21		22,23,24							
Column 1 B	SW	A	3789	10/16/13	1200		2	20,21		22,23,24							
Column 1 C	SW	A	3790	10/16/13	1200		2	20,21		22,23,24							
Column 2 A	SW	A	3791	10/16/13	1200		2	20,21		22,23,24							
Column 2 B	SW	A	3792	10/16/13	1200		2	20,21		22,23,24							
Column 2 C	SW	A	3793	10/16/13	1200		2	20,21		22,23,24							
Column 3 A	SW	A	3794	10/16/13	1200		2	20,21		22,23,24							
Column 3 B	SW	A	3795	10/16/13	1200		2	20,21		22,23,24							
Column 3 C	SW	A	3796	10/16/13	1200		2	20,21		22,23,24							
Influent I	SW	A	3797	10/16/13	1200		2	20,21		22,23,24							
Influent II	SW	A	13-3798	10/16/13	1200			20,21		22,23,24							
					DISPOSAL DATE:												

COMMENTS:

CUSTODY TRANSFERS

Relinquished By	Received By	Date	Time
1. [signature]	[signature]	10/16/13	1430
2.			

Method of Shipment:

Delivered Directly to Lab: X

Shipped By FedEx: ____ UPS: ____ Other: ____

Received in Cooler: ✓ Y ___ N

Temperature: 4 °C

Shipped in Ice: ✓ Y ___ N

Ice Present: ✓ Y ___ N

pH Checked in Laboratory (< 2 s.u.): ✓ Y ___ N

Chlorine Check (< 0.1 mg/l): ✓ ___ Y ___ N

*MATRIX: SW=Stormwater SP=Seepage S=Surface Water BF=Baseflow GW=Groundwater BP=Bulk Precipitation G=Grab C=Composite

**ICE PRESERVATION CODES (IPC): A=Transported on ice, ice present when received B=Transported on ice, ice not present when received C=Not transported on ice

Page N____

ENVIRONMENTAL RESEARCH & DESIGN, INC. ----- CHAIN-OF-CUSTODY RECORD

3419 Trentwood Blvd., Suite 102 - Orlando, FL 32812 - Phone: (407) 855-9465 - Fax: (407) 826-0419

Client Name: UCF Storm Water Academy

Address:

Project Manager: Phone:

Project Name: BAM Project Number:

Containers Accepted By: Cassie Pelto

Samples Collected By: Andrew Hood

IDENTIFIER CODES / NUMBER OF SAMPLE BOTTLES COLLECTED

Sample I.D.	*Matrix	**IPC	ERD Sample I.D. No.	Date Collected	Time Collected	1- Gallon Plastic (BP)	1-Liter Glass	60 mL Plastic (Filtered)	60 mL Plastic (Filtered/ Preserved w/ H_2SO_4)	60 mL Plastic (Preserved w/ H_2SO_4)	250 ml Plastic (SP)	Glass (Preserved w/ HCl)	Metals: 250 ml Plastic (Preserved w/ HNO_3) UF	Metals: 250 ml Plastic (Preserved w/ HNO_3) F	Whirlpak	Other	Other
Identifier code								F	FP	P	SP	OG	M	FM	W		
Number collected							10	11		11							
Column 1 A	SW	A	13-3807	10/18/13	0900		2	20,21		22,23,24							
Column 1 B	SW	A	3808	10/18/13	0900		2	20,21		22,23,24							
Column 1 C	SW	A	3809	10/18/13	0900		2	20,21		22,23,24							
Column 2 A	SW	A	3810	10/18/13	0900		2	20,21		22,23,24							
Column 2 B	SW	A	3811	10/18/13	0900		2	20,21		22,23,24							
Column 2 C	SW	A	3812	10/18/13	0900		2	20,21		22,23,24							
Column 3 A	SW	A	3813	10/18/13	0900		2	20,21		22,23,24							
Column 3 B	SW	A	3814	10/18/13	0900		2	20,21		22,23,24							
Column 3 C	SW	A	3815	10/18/13	0900		2	20,21		22,23,24							
Influent I	SW	A	3816	10/18/13	0900		2	20,21		22,23,24							
Influent II	SW	A	3817	10/18/13	0900			20,21		22,23,24							
					DISPOSAL DATE:												

COMMENTS:

CUSTODY TRANSFERS

	Relinquished By	Received By	Date	Time
1.	Chad Meitel	Ambur	10/18/13	1200
2.				

Method of Shipment:

Delivered Directly to Lab: X

Shipped By FedEx: ______ UPS: ______ Other: ______

Received in Cooler: ___Y ___N

Temperature: ______°C

Shipped in Ice: ___Y ___N

Ice Present: ___Y ___N

pH Checked in Laboratory (< 2 s.u.): ___Y ___N

Chlorine Check (< 0.1 mg/l): ___Y ___N

*MATRIX: SW=Stormwater SP=Seepage S=Surface Water BF=Baseflow GW=Groundwater BP=Bulk Precipitation G=Grab C=Composite

**ICE PRESERVATION CODES (IPC): A=Transported on ice, ice present when received B=Transported on ice, ice not present when received C=Not transported on ice

Page No.

ENVIRONMENTAL RESEARCH & DESIGN, INC. ----- CHAIN-OF-CUSTODY RECORD

3419 Trentwood Blvd., Suite 102 - Orlando, FL 32812 - Phone: (407) 855-9465 - Fax: (407) 826-0419

Client Name: UCF Storm Water Academy

Address:

Project Manager: Phone:

Project Name: BAM Project Number:

Containers Accepted By: Cassie Pelto

Samples Collected By: Andrew Hood

Sample I.D.	*Matrix	**IPC	ERD Sample I.D. No.	Date Collected	Time Collected	1- Gallon Plastic (BP)	1-Liter Glass	60 mL Plastic (Filtered)	60 mL Plastic (Filtered/ Preserved w/ H_2SO_4)	60 mL Plastic (Preserved w/ H_2SO_4)	250 ml Plastic (SP)	Glass (Preserved w/ HCl)	Metals: UF	250 ml Plastic (Preserved w/ HNO_3) F	Whirlpak	Other	Other
IDENTIFIER CODES								F	FP	P	SP	OG	M	FM	W		
NUMBER OF SAMPLE BOTTLES COLLECTED							10	11		11							
Column 1 A	SW	A	13-3861	10/23/13	1000		2	20,21		22,23,24							
Column 1 B	SW	A	3862	10/23/13	1000		2	20,21		22,23,24							
Column 1 C	SW	A	3863	10/23/13	1000		2	20,21		22,23,24							
Column 2 A	SW	A	3864	10/23/13	1000		2	20,21		22,23,24							
Column 2 B	SW	A	3865	10/23/13	1000		2	20,21		22,23,24							
Column 2 C	SW	A	3866	10/23/13	1000		2	20,21		22,23,24							
Column 3 A	SW	A	3867	10/23/13	1000		2	20,21		22,23,24							
Column 3 B	SW	A	3868	10/23/13	1000		2	20,21		22,23,24							
Column 3 C	SW	A	3869	10/23/13	1000		2	20,21		22,23,24							
Influent I	SW	A	3870	10/23/13	1000		2	20,21		22,23,24							
Influent II	SW	A	3871	10/23/13	1000			20,21		22,23,24							
					DISPOSAL DATE:												

COMMENTS:

CUSTODY TRANSFERS			
Relinquished By	Received By	Date	Time
1. Eld Mun	Amber Men	10/23/13	12:00
2.			

Method of Shipment:

Delivered Directly to Lab: X

Shipped By FedEx: ____ UPS: ____ Other: ____

Received in Cooler: ✓ Y ___ N

Temperature: 4 °C

Shipped in Ice: ✓ Y ___ N

Ice Present: ✓ Y ___ N

pH Checked in Laboratory (< 2 s.u.): ✓ Y ___ N

Chlorine Check (< 0.1 mg/l): ___ Y ✓ N

*MATRIX: SW=Stormwater SP=Seepage S=Surface Water BF=Baseflow GW=Groundwater BP=Bulk Precipitation G=Grab C=Composite

**ICE PRESERVATION CODES (IPC): A=Transported on ice, ice present when received B=Transported on ice, ice not present when received C=Not transported on ice

Page No. ___

ENVIRONMENTAL RESEARCH & DESIGN, INC. ----- CHAIN-OF-CUSTODY RECORD

3419 Trentwood Blvd., Suite 102 - Orlando, FL 32812 - Phone: (407) 855-9465 - Fax: (407) 826-0419

Client Name: UCF Storm Water Academy

Address:

Project Manager: Phone:

Project Name: BAM Project Number:

Containers Accepted By: Andrew F.

Samples Collected By:

IDENTIFIER CODES / NUMBER OF SAMPLE BOTTLES COLLECTED

Sample I.D.	*Matrix	**IPC	ERD Sample I.D. No.	Date Collected	Time Collected	1-Gallon Plastic (BP)	1-Liter Glass	F: 60 mL Plastic (Filtered)	FP: 60 mL Plastic (Filtered/ Preserved w/ H_2SO_4)	P: 60 mL Plastic (Preserved w/ H_2SO_4)	SP: 250 ml Plastic (SP)	OG: Glass (Preserved w/ HCl)	M: Metals: 250 ml Plastic (Preserved w/ HNO_3) UF	FM: F	W: Whirlpak	Other ___	Other ___
Number of bottles							10	11		11							
Column 1 A	SW	A	13-3895	10/25/13	1100		2	20,21		22,23,24							
Column 1 B	SW	A	13-3896	10/25/13	1100		2	20,21		22,23,24							
Column 1 C	SW	A	13-3897	10/25/13	1100		2	20,21		22,23,24							
Column 2 A	SW	A	13-3898	10/25/13	1100		2	20,21		22,23,24							
Column 2 B	SW	A	13-3899	10/25/13	1100		2	20,21		22,23,24							
Column 2 C	SW	A	13-3900	10/25/13	1100		2	20,21		22,23,24							
Column 3 A	SW	A	13-3901	10/25/13	1100		2	20,21		22,23,24							
Column 3 B	SW	A	13-3902	10/25/13	1100		2	20,21		22,23,24							
Column 3 C	SW	A	13-3903	10/25/13	1100		2	20,21		22,23,24							
Influent I	SW	A	13-3904	10/25/13	1100		2	20,21		22,23,24							
Influent II	SW	A	13-3905	10/25/13	1100			20,21		22,23,24							
					DISPOSAL DATE:												

COMMENTS:

CUSTODY TRANSFERS			
Relinquished By	Received By	Date	Time
1. Chris Mesa	[signature]	10/25/13	1400
2.			

Method of Shipment:

Delivered Directly to Lab: X

Shipped By FedEx: ___ UPS: ___ Other: ___

Received in Cooler: ✓ Y ___ N

Temperature: 4 °C

Shipped in Ice: ✓ Y ___ N

Ice Present: ✓ Y ___ N

pH Checked in Laboratory (< 2 s.u.): ✓ Y ___ N

Chlorine Check (< 0.1 mg/l): ___ Y ✓ N

*MATRIX: SW=Stormwater SP=Seepage S=Surface Water BF=Baseflow GW=Groundwater BP=Bulk Precipitation G=Grab C=Composite

**ICE PRESERVATION CODES (IPC): A=Transported on ice, ice present when received B=Transported on ice, ice not present when received C=Not transported on ice

Page No ___

ENVIRONMENTAL RESEARCH & DESIGN, INC. ----- CHAIN-OF-CUSTODY RECORD

3419 Trentwood Blvd., Suite 102 - Orlando, FL 32812 - Phone: (407) 855-9465 - Fax: (407) 826-0419

Client Name: UCF Storm Water Academy

Address:

Project Manager: Phone:

Project Name: BAM Project Number:

Containers Accepted By:

Samples Collected By:

						IDENTIFIER CODES											
								F	FP	P	SP	OG	M	FM	W		
						NUMBER OF SAMPLE BOTTLES COLLECTED											
							10	11		11							
Sample I.D.	*Matrix	**IPC	ERD Sample I.D. No.	Date Collected	Time Collected	1- Gallon Plastic (BP)	1-Liter Glass	60 mL Plastic (Filtered)	60 mL Plastic (Filtered/ Preserved w/ H_2SO_4)	60 mL Plastic (Preserved w/ H_2SO_4)	250 ml Plastic (SP)	Glass (Preserved w/ HCl)	Metals: 250 ml Plastic (Preserved w/ HNO_3) UF	F	Whirlpak	Other ___	Other ___
Column 1 A	SW	A	13-3966	10/29/13	1000		2	20,21		22,23,24							
Column 1 B	SW	A	3967	10/29/13	1000		2	20,21		22,23,24							
Column 1 C	SW	A	3968	10/29/13	1000		2	20,21		22,23,24							
Column 2 A	SW	A	3969	10/29/13	1000		2	20,21		22,23,24							
Column 2 B	SW	A	3970	10/29/13	1000		2	20,21		22,23,24							
Column 2 C	SW	A	3971	10/29/13	1000		2	20,21		22,23,24							
Column 3 A	SW	A	3972	10/29/13	1000		2	20,21		22,23,24							
Column 3 B	SW	A	3973	10/29/13	1000		2	20,21		22,23,24							
Column 3 C	SW	A	3974	10/29/13	1000		2	20,21		22,23,24							
Influent I	SW	A	3975	10/29/13	1000		2	20,21		22,23,24							
Influent II	SW	A	3976	10/29/13	1000			20,21		22,23,24							
					DISPOSAL DATE:												

COMMENTS:

CUSTODY TRANSFERS			
Relinquished By	Received By	Date	Time
1. [illegible signature]	[illegible signature]	10/30/13	1230
2.			

Method of Shipment:

Delivered Directly to Lab: X

Shipped By FedEx: ___ UPS: ___ Other: ___

Received in Cooler: ✓ Y ___ N

Temperature: 6 °C

Shipped in Ice: ✓ Y ___ N

Ice Present: ✓ Y ___ N

pH Checked in Laboratory (< 2 s.u.): ✓ Y ___ N

Chlorine Check (< 0.1 mg/l): ___ Y ✓ N

*MATRIX: SW=Stormwater SP=Seepage S=Surface Water BF=Baseflow GW=Groundwater BP=Bulk Precipitation G=Grab C=Composite

**ICE PRESERVATION CODES (IPC): A=Transported on ice, ice present when received B=Transported on ice, ice not present when received C=Not transported on ice

Pag ____

ENVIRONMENTAL RESEARCH & DESIGN, INC. ----- CHAIN-OF-CUSTODY RECORD
3419 Trentwood Blvd., Suite 102 - Orlando, FL 32812 - Phone: (407) 855-9465 - Fax: (407) 826-0419

Client Name: UCF Storm Water Academy
Address:
Project Manager: Phone:
Project Name: BAM Project Number:
Containers Accepted By:
Samples Collected By:

IDENTIFIER CODES / NUMBER OF SAMPLE BOTTLES COLLECTED

Sample I.D.	*Matrix	**IPC	ERD Sample I.D. No.	Date Collected	Time Collected	1-Gallon Plastic (BP)	1-Liter Glass	60 mL Plastic (Filtered)	60 mL Plastic (Filtered/ Preserved w/ H_2SO_4)	60 mL Plastic (Preserved w/ H_2SO_4)	250 ml Plastic (SP)	Glass (Preserved w/ HCl)	Metals: 250 ml Plastic (Preserved w/ HNO_3) UF	F	Whirlpak	Other	Other
Identifier code								F	FP	P	SP	OG	M	FM	W		
Number of bottles							10	11		11							
Column 1 A	SW	A	13-3993	11/1/13	1100		2	20,21		22,23,24							
Column 1 B	SW	A	3994	11/1/13	1100		2	20,21		22,23,24							
Column 1 C	SW	A	3995	11/1/13	1100		2	20,21		22,23,24							
Column 2 A	SW	A	3996	11/1/13	1100		2	20,21		22,23,24							
Column 2 B	SW	A	3997	11/1/13	1100		2	20,21		22,23,24							
Column 2 C	SW	A	3998	11/1/13	1100		2	20,21		22,23,24							
Column 3 A	SW	A	3999	11/1/13	1100		2	20,21		22,23,24							
Column 3 B	SW	A	4000	11/1/13	1100		2	20,21		22,23,24							
Column 3 C	SW	A	4001	11/1/13	1100		2	20,21		22,23,24							
Influent I	SW	A	4002	11/1/13	1100		2	20,21		22,23,24							
Influent II	SW	A	4003	11/1/13	1100			20,21		22,23,24							
					DISPOSAL DATE:			12/17/13 ok									

COMMENTS:

CUSTODY TRANSFERS			
Relinquished By	Received By	Date	Time
1. Andy Ci[illegible]	Ambeam[illegible]	11/1/13	1347
2.			

Method of Shipment:
Delivered Directly to Lab: X
Shipped By FedEx: ____ UPS: ____ Other: ____

Received in Cooler: ✓ Y ___ N
Temperature: 4 °C
Shipped in Ice: ✓ Y ___ N
Ice Present: ✓ Y ___ N

pH Checked in Laboratory (< 2 s.u.): ✓ Y ___ N
Chlorine Check (< 0.1 mg/l): ___ Y ✓ N

*MATRIX: SW=Stormwater SP=Seepage S=Surface Water BF=Baseflow GW=Groundwater BP=Bulk Precipitation G=Grab C=Composite
**ICE PRESERVATION CODES (IPC): A=Transported on ice, ice present when received B=Transported on ice, ice not present when received C=Not transported on ice

Page No ___

ENVIRONMENTAL RESEARCH & DESIGN, INC. ----- CHAIN-OF-CUSTODY RECORD

3419 Trentwood Blvd., Suite 102 - Orlando, FL 32812 - Phone: (407) 855-9465 - Fax: (407) 826-0419

Client Name: UCF Storm Water Academy

Address:

Project Manager: Phone:

Project Name: BAM Project Number:

Containers Accepted By: Cassie Pelto

Samples Collected By: Chad M.

IDENTIFIER CODES / NUMBER OF SAMPLE BOTTLES COLLECTED

Sample I.D.	*Matrix	**IPC	ERD Sample I.D. No.	Date Collected	Time Collected	1- Gallon Plastic (BP)	1-Liter Glass	60 mL Plastic (Filtered)	60 mL Plastic (Filtered/ Preserved w/ H_2SO_4)	60 mL Plastic (Preserved w/ H_2SO_4)	250 ml Plastic (SP)	Glass (Preserved w/ HCl)	Metals: UF	250 ml Plastic (Preserved w/ HNO_3) F	Whirlpak	Other	Other
Identifier codes								F	FP	P	SP	OG	M	FM	W		
Number of bottles							10	11		11							
Column 1 A	SW	A	13-4023	11/5/13	0900		2	20,21		22,23,24							
Column 1 B	SW	A	4024	11/5/13	0900		2	20,21		22,23,24							
Column 1 C	SW	A	4025	11/5/13	0900		2	20,21		22,23,24							
Column 2 A	SW	A	4026	11/5/13	0900		2	20,21		22,23,24							
Column 2 B	SW	A	4027	11/5/13	0900		2	20,21		22,23,24							
Column 2 C	SW	A	4028	11/5/13	0900		2	20,21		22,23,24							
Column 3 A	SW	A	4029	11/5/13	0900		2	20,21		22,23,24							
Column 3 B	SW	A	4030	11/5/13	0900		2	20,21		22,23,24							
Column 3 C	SW	A	4031	11/5/13	0900		2	20,21		22,23,24							
Influent I	SW	A	4032	11/5/13	0900		2	20,21		22,23,24							
Influent II	SW	A	4033	11/5/13	0900			20,21		22,23,24							
					DISPOSAL DATE:												

COMMENTS:

CUSTODY TRANSFERS Relinquished By	Received By	Date	Time
1. Eric Meinser	Cassie Pelto	11/6/13	1245
2.			

Method of Shipment:
Delivered Directly to Lab: X
Shipped By FedEx: ___ UPS: ___ Other: ___

Received in Cooler: ✓ Y ___ N
Temperature: 4 °C
Shipped in Ice: ✓ Y ___ N
Ice Present: ✓ Y ___ N

pH Checked in Laboratory (< 2 s.u.): ✓ Y ___ N
Chlorine Check (< 0.1 mg/l): ___ Y ✓ N

*MATRIX: SW=Stormwater SP=Seepage S=Surface Water BF=Baseflow GW=Groundwater BP=Bulk Precipitation G=Grab C=Composite

**ICE PRESERVATION CODES (IPC): A=Transported on ice, ice present when received B=Transported on ice, ice not present when received C=Not transported on ice

Page No. ___

ENVIRONMENTAL RESEARCH & DESIGN INC. ----- CHAIN-OF-CUSTODY RECORD

3419 Trentwood Blvd., Suite 102 - Orlando, FL 32812 - Phone: (407) 855-9465 - Fax: (407) 826-0419

Client Name: UCF Storm Water Academy

Address:

Project Manager: | Phone:

Project Name: BAM | Project Number:

Containers Accepted By: Amber Maroon

Samples Collected By: Amber 11/8 AM

						IDENTIFIER CODES											
								F	FP	P	SP	OG	M	FM	W		
						NUMBER OF SAMPLE BOTTLES COLLECTED											
							10	11		11							
Sample I.D.	*Matrix	**IPC	ERD Sample I.D. No.	Date Collected	Time Collected	1- Gallon Plastic (BP)	1-Liter Glass	60 mL Plastic (Filtered)	60 mL Plastic (Filtered/ Preserved w/ H_2SO_4)	60 mL Plastic (Preserved w/ H_2SO_4)	250 ml Plastic (SP)	Glass (Preserved w/ HCl)	Metals: UF	250 ml Plastic (Preserved w/ HNO_3) F	Whirlpak	Other ___	Other ___
Column 1 A	SW	A	13-4060	11/8/13	1000		2	20,21		22,23,24							
Column 1 B	SW	A	4061	11/8/13	1000		2	20,21		22,23,24							
Column 1 C	SW	A	4062	11/8/13	1000		2	20,21		22,23,24							
Column 2 A	SW	A	4063	11/8/13	1000		2	20,21		22,23,24							
Column 2 B	SW	A	4064	11/8/13	1000		2	20,21		22,23,24							
Column 2 C	SW	A	4065	11/8/13	1000		2	20,21		22,23,24							
Column 3 A	SW	A	4066	11/8/13	1000		2	20,21		22,23,24							
Column 3 B	SW	A	4067	11/8/13	1000		2	20,21		22,23,24							
Column 3 C	SW	A	4068	11/8/13	1000		2	20,21		22,23,24							
Influent I	SW	A	4069	11/8/13	1000		2	20,21		22,23,24							
Influent II	SW	A	4070	11/8/13	1000			20,21		22,23,24							
					DISPOSAL DATE:												

COMMENTS:

CUSTODY TRANSFERS			
Relinquished By	Received By	Date	Time
1. [signature]	[signature]	11/8/13	1225
2.			

Method of Shipment:

Delivered Directly to Lab: X

Shipped By FedEx: ___ UPS: ___ Other: ___

Received in Cooler: ✓ Y ___ N

Temperature: 4 °C

Shipped in Ice: ✓ Y ___ N

Ice Present: ✓ Y ___ N

pH Checked in Laboratory (< 2 s.u.): ✓ Y ___ N

Chlorine Check (< 0.1 mg/l): ___ Y ✓ N

*MATRIX: SW=Stormwater SP=Seepage S=Surface Water BF=Baseflow GW=Groundwater BP=Bulk Precipitation G=Grab C=Composite

**ICE PRESERVATION CODES (IPC): A=Transported on ice, ice present when received B=Transported on ice, ice not present when received C=Not transported on ice

Page No. 1

ENVIRONMENTAL RESEARCH & DESIGN, INC. ----- CHAIN-OF-CUSTODY RECORD

3419 Trentwood Blvd., Suite 102 - Orlando, FL 32812 - Phone: (407) 855-9465 - Fax: (407) 826-0419

Client Name: UCF Storm Water Academy

Address:

Project Manager: Phone:

Project Name: BAM Project Number:

Containers Accepted By: Amber Maroon

Samples Collected By:

Sample I.D.	*Matrix	**IPC	ERD Sample I.D. No.	Date Collected	Time Collected	1-Gallon Plastic (BP)	1-Liter Glass	60 mL Plastic (Filtered)	60 mL Plastic (Filtered/ Preserved w/ H_2SO_4)	60 mL Plastic (Preserved w/ H_2SO_4)	250 ml Plastic (SP)	Glass (Preserved w/ HCl)	Metals: 250 ml Plastic (Preserved w/ HNO_3) UF	Metals: 250 ml Plastic (Preserved w/ HNO_3) F	Whirlpak	Other	Other
IDENTIFIER CODES								F	FP	P	SP	OG	M	FM	W		
NUMBER OF SAMPLE BOTTLES COLLECTED							10	11		11							
Column 1 A	SW	A	13-4102	11/13/13	1000			20,21		22,23,24							
Column 1 B	SW	A	4103	11/13/13	1000		2	20,21		22,23,24							
Column 1 C	SW	A	4104	11/13/13	1000		2	20,21		22,23,24							
Column 2 A	SW	A	4105	11/13/13	1000		2	20,21		22,23,24							
Column 2 B	SW	A	4106	11/13/13	1000		2	20,21		22,23,24							
Column 2 C	SW	A	4107	11/13/13	1000		2	20,21		22,23,24							
Column 3 A	SW	A	4108	11/13/13	1000		2	20,21		22,23,24							
Column 3 B	SW	A	4109	11/13/13	1000		2	20,21		22,23,24							
Column 3 C	SW	A	4110	11/13/13	1000		2	20,21		22,23,24							
Influent I	SW	A	4111	11/13/13	1000		2	20,21		22,23,24							
Influent II	SW	A	4112	11/13/13	1000			20,21		22,23,24							
				DISPOSAL DATE:													

COMMENTS:

CUSTODY TRANSFERS			
Relinquished By	Received By	Date	Time
1. [signature]	[signature]	11/13/13	1223
2.			

Method of Shipment:

Delivered Directly to Lab: X

Shipped By FedEx: ____ UPS: ____ Other: ____

Received in Cooler: ✓ Y ___ N

Temperature: 4 °C

Shipped in Ice: ✓ Y ___ N

Ice Present: ✓ Y ___ N

pH Checked in Laboratory (< 2 s.u.): ✓ Y ___ N

Chlorine Check (< 0.1 mg/l): ___ Y ✓ N

*MATRIX: SW=Stormwater SP=Seepage S=Surface Water BF=Baseflow GW=Groundwater BP=Bulk Precipitation G=Grab C=Composite

**ICE PRESERVATION CODES (IPC): A=Transported on ice, ice present when received B=Transported on ice, ice not present when received C=Not transported on ice

Page No. ____

ENVIRONMENTAL RESEARCH & DESIGN INC. ----- CHAIN-OF-CUSTODY RECORD

3419 Trentwood Blvd., Suite 102 - Orlando, FL 32812 - Phone: (407) 855-9465 - Fax: (407) 826-0419

Client Name: UCF Storm Water Academy

Address:

Project Manager: Phone:

Project Name: BAM Project Number:

Containers Accepted By: Amber Maroon

Samples Collected By:

						IDENTIFIER CODES											
								F	FP	P	SP	OG	M	FM	W		
						NUMBER OF SAMPLE BOTTLES COLLECTED											
							10	11		11							
Sample I.D.	*Matrix	**IPC	ERD Sample I.D. No.	Date Collected	Time Collected	1- Gallon Plastic (BP)	1-Liter Glass	60 mL Plastic (Filtered)	60 mL Plastic (Filtered/ Preserved w/ H_2SO_4)	60 mL Plastic (Preserved w/ H_2SO_4)	250 ml Plastic (SP)	Glass (Preserved w/ HCl)	Metals: UF	250 ml Plastic (Preserved w/ HNO_3) F	Whirlpak	Other	Other
Column 1 A	SW	A	13-4120	11/15/13	1000		2	20,21		22,23,24							
Column 1 C	SW	A	13-4121	11/15/13	1000		2	20,21		22,23,24							
Column 2 A	SW	A	4122	11/15/13	1000		2	20,21		22,23,24							
Column 2 B	SW	A	4123	11/15/13	1000		2	20,21		22,23,24							
Column 2 C	SW	A	4124	11/15/13	1000		2	20,21		22,23,24							
Column 3 A	SW	A	4125	11/15/13	1000		2	20,21		22,23,24							
Column 3 B	SW	A	4126	11/15/13	1000		2	20,21		22,23,24							
Column 3 C	SW	A	4127	11/15/13	1000		2	20,21		22,23,24							
Influent I	SW	A	4128	11/15/13	1000		2	20,21		22,23,24							
Influent II	SW	A	4129	11/15/13	1000			20,21		22,23,24							
					DISPOSAL DATE:												

COMMENTS:

CUSTODY TRANSFERS			
Relinquished By	Received By	Date	Time
1. Uhd Mc	Amberm	11/15/13	1239
2.			

Method of Shipment:

Delivered Directly to Lab: X

Shipped By FedEx: ____ UPS: ____ Other: ____

Received in Cooler: ✓ Y ___N

Temperature: 4 °C

Shipped in Ice: ✓ Y ___N

Ice Present: ✓ Y ___N

pH Checked in Laboratory (< 2 s.u.): ____Y ____N

Chlorine Check (< 0.1 mg/l): ____Y ____N

*MATRIX: SW=Stormwater SP=Seepage S=Surface Water BF=Baseflow GW=Groundwater BP=Bulk Precipitation G=Grab C=Composite

**ICE PRESERVATION CODES (IPC): A=Transported on ice, ice present when received B=Transported on ice, ice not present when received C=Not transported on ice

Page No ___

ENVIRONMENTAL RESEARCH & DESIGN, INC. ----- CHAIN-OF-CUSTODY RECORD

3419 Trentwood Blvd., Suite 102 - Orlando, FL 32812 - Phone: (407) 855-9465 - Fax: (407) 826-0419

Client Name: UCF Storm Water Academy

Address:

Project Manager: Phone:

Project Name: BAM Project Number:

Containers Accepted By: Cassie Pelto

Samples Collected By: Drew Hood

Sample I.D.	*Matrix	**IPC	ERD Sample I.D. No.	Date Collected	Time Collected	1- Gallon Plastic (BP)	1-Liter Glass	60 mL Plastic (Filtered)	60 mL Plastic (Filtered/ Preserved w/ H_2SO_4)	60 mL Plastic (Preserved w/ H_2SO_4)	250 ml Plastic (SP)	Glass (Preserved w/ HCl)	Metals: 250 ml Plastic (Preserved w/ HNO_3) UF	Metals: 250 ml Plastic (Preserved w/ HNO_3) F	Whirlpak	Other	Other
Identifier codes								F	FP	P	SP	OG	M	FM	W		
Number of sample bottles collected							10	11		11							
Column 1 A	SW	A	13-4169	11/19/13	1000		2	20,21		22,23,24							
Column 1 B	SW	A	4170	11/19/13	1000		2	20,21		22,23,24							
Column 1 C	SW	A	4171	11/19/13	1000		2	20,21		22,23,24							
Column 2 A	SW	A	4172	11/19/13	1000		2	20,21		22,23,24							
Column 2 B	SW	A	4173	11/19/13	1000		2	20,21		22,23,24							
Column 2 C	SW	A	4174	11/19/13	1000		2	20,21		22,23,24							
Column 3 A	SW	A	4175	11/19/13	1000		2	20,21		22,23,24							
Column 3 B	SW	A	4176	11/19/13	1000		2	20,21		22,23,24							
Column 3 C	SW	A	4177	11/19/13	1000		2	20,21		22,23,24							
Influent I	SW	A	4178	11/19/13	1000		2	20,21		22,23,24							
Influent II	SW	A	13-4179	11/19/13	1000			20,21		22,23,24							
				DISPOSAL DATE:													

COMMENTS:

CUSTODY TRANSFERS: Relinquished By	Received By	Date	Time
1. [signature]	[signature]	11/20/13	1500
2.			

Method of Shipment:

Delivered Directly to Lab: X

Shipped By FedEx: ____ UPS: ____ Other: ____

Received in Cooler: ✓ Y ___N

Temperature: 4 °C

Shipped in Ice: ✓ Y ___N

Ice Present: ✓ Y ___N

pH Checked in Laboratory (< 2 s.u.): ✓ Y ___N

Chlorine Check (< 0.1 mg/l): ___Y ✓ N

*MATRIX: SW=Stormwater SP=Seepage S=Surface Water BF=Baseflow GW=Groundwater BP=Bulk Precipitation G=Grab C=Composite

**ICE PRESERVATION CODES (IPC): A=Transported on ice, ice present when received B=Transported on ice, ice not present when received C=Not transported on ice

Page No. ___

ENVIRONMENTAL RESEARCH & DESIGN, INC. ----- CHAIN-OF-CUSTODY RECORD

3419 Trentwood Blvd., Suite 102 - Orlando, FL 32812 - Phone: (407) 855-9465 - Fax: (407) 826-0419

Client Name: UCF Storm Water Academy

Address:

Project Manager: Phone:

Project Name: BAM Project Number:

Containers Accepted By: Cassie Pelto

Samples Collected By: Drew Hood

IDENTIFIER CODES / NUMBER OF SAMPLE BOTTLES COLLECTED

Sample I.D.	*Matrix	**IPC	ERD Sample I.D. No.	Date Collected	Time Collected	1- Gallon Plastic (BP)	1-Liter Glass	60 mL Plastic (Filtered)	60 mL Plastic (Filtered/ Preserved w/ H_2SO_4)	60 mL Plastic (Preserved w/ H_2SO_4)	250 ml Plastic (SP)	Glass (Preserved w/ HCl)	Metals: 250 ml Plastic (Preserved w/ HNO_3) UF	Metals: 250 ml Plastic (Preserved w/ HNO_3) F	Whirlpak	Other	Other
								F	FP	P	SP	OG	M	FM	W		
								9									
Column 1 A – 2 hr Grab	SW	A	13-4180	11/19/13	1000			20									
Column 1 A – 2 hr Tub	SW	A	4181	11/19/13	1000			20									
Column 1 A – 24 hr Grab	SW	A	4182	11/19/13	1000			20									
Column 2 A – 2 hr Grab	SW	A	4183	11/19/13	1000			20									
Column 2 A – 2 hr Tub	SW	A	4184	11/19/13	1000			20									
Column 2 A – 24 hr Grab	SW	A	4185	11/19/13	1000			20									
Column 3 A – 2 hr Grab	SW	A	4186	11/19/13	1000			20									
Column 3 A – 2 hr Tub	SW	A	4187	11/19/13	1000			20									
Column 3 A – 24 hr Grab	SW	A	13-4188	11/19/13	1000			20									
				DISPOSAL DATE:													

COMMENTS:

CUSTODY TRANSFERS

Relinquished By	Received By	Date	Time
1. [signature]	[signature: Cassie Pelto]	11/20/13	1500
2.			

Method of Shipment:

Delivered Directly to Lab: X

Shipped By FedEx: ___ UPS: ___ Other: ___

Received in Cooler: ✓ Y ___ N

Temperature: 4 °C

Shipped in Ice: ✓ Y ___ N

Ice Present: ✓ Y ___ N

pH Checked in Laboratory (< 2 s.u.): ✓ Y ___ N

Chlorine Check (< 0.1 mg/l): ___ Y ✓ N

*MATRIX: SW=Stormwater SP=Seepage S=Surface Water BF=Baseflow GW=Groundwater BP=Bulk Precipitation G=Grab C=Composite

**ICE PRESERVATION CODES (IPC): A=Transported on ice, ice present when received B=Transported on ice, ice not present when received C=Not transported on ice

Page No. ___

ENVIRONMENTAL RESEARCH & DESIGN, INC. ----- CHAIN-OF-CUSTODY RECORD

3419 Trentwood Blvd., Suite 102 - Orlando, FL 32812 - Phone: (407) 855-9465 - Fax: (407) 826-0419

Client Name: UCF Storm Water Academy

Address:

Project Manager: Phone:

Project Name: BAM Project Number:

Containers Accepted By: Amber Maroon

Samples Collected By: Drew Hood

					IDENTIFIER CODES											
							F	FP	P	SP	OG	M	FM	W		
					NUMBER OF SAMPLE BOTTLES COLLECTED											
						10	11		11							
Sample I.D.	*Matrix	**IPC	ERD Sample I.D. No.	Date Collected	Time Collected	1-Gallon Plastic (BP)	1-Liter Glass	60 mL Plastic (Filtered)	60 mL Plastic (Filtered/ Preserved w/ H_2SO_4)	60 mL Plastic (Preserved w/ H_2SO_4)	250 ml Plastic (SP)	Glass (Preserved w/ HCl)	Metals: UF	250 ml Plastic (Preserved w/ HNO_3) F	Whirlpak	Other___	Other___
Column 1 A	SW	A	13-4239	11/22/13	1100		2	20,21		22,23,24							
Column 1 B	SW	A	4240	11/22/13	1100		2	20,21		22,23,24							
Column 1 C	SW	A	4241	11/22/13	1100		2	20,21		22,23,24							
Column 2 A	SW	A	4242	11/22/13	1100		2	20,21		22,23,24							
Column 2 B	SW	A	4243	11/22/13	1100		2	20,21		22,23,24							
Column 2 C	SW	A	4244	11/22/13	1100		2	~~20,21~~ am 11/22		22,23,24							
Column 3 A	SW	A	4245	11/22/13	1100		2	20,21		22,23,24							
Column 3 B	SW	A	4246	11/22/13	1100		2	20,21		22,23,24							
Column 3 C	SW	A	4247	11/22/13	1100		2	20,21		22,23,24							
Influent I	SW	A	4248	11/22/13	1100		2	20,21		22,23,24							
Influent II	SW	A	4249	11/22/13	1100			20,21		22,23,24							
					DISPOSAL DATE:											

COMMENTS:

CUSTODY TRANSFERS			
Relinquished By	Received By	Date	Time
1. Eli Mc	Amber Maroon	11/22/13	1500
2.			

Method of Shipment:

Delivered Directly to Lab: X

Shipped By FedEx: ____ UPS: ____ Other: ____

Received in Cooler: ___Y ___N

Temperature: ______°C

Shipped in Ice: ___Y ___N

Ice Present: ___Y ___N

pH Checked in Laboratory (< 2 s.u.): ___Y ___N

Chlorine Check (< 0.1 mg/l): ___Y ___N

*MATRIX: SW=Stormwater SP=Seepage S=Surface Water BF=Baseflow GW=Groundwater BP=Bulk Precipitation G=Grab C=Composite

**ICE PRESERVATION CODES (IPC): A=Transported on ice, ice present when received B=Transported on ice, ice not present when received C=Not transported on ice

Page No. 7

ENVIRONMENTAL RESEARCH & DESIGN, INC. ----- CHAIN-OF-CUSTODY RECORD

3419 Trentwood Blvd., Suite 102 - Orlando, FL 32812 - Phone: (407) 855-9465 - Fax: (407) 826-0419

Client Name: UCF Storm Water Academy

Address:

Project Manager: Phone:

Project Name: BAM Project Number:

Containers Accepted By: Cassie Pelto

Samples Collected By: Drew Hood

IDENTIFIER CODES / NUMBER OF SAMPLE BOTTLES COLLECTED

Sample I.D.	*Matrix	**IPC	ERD Sample I.D. No.	Date Collected	Time Collected	1-Gallon Plastic (BP)	1-Liter Glass	60 mL Plastic (Filtered)	60 mL Plastic (Filtered/ Preserved w/ H_2SO_4)	60 mL Plastic (Preserved w/ H_2SO_4)	250 ml Plastic (SP)	Glass (Preserved w/ HCl)	Metals: UF	250 ml Plastic (Preserved w/ HNO_3) F	Whirlpak	Other	Other
Identifier code								F	FP	P	SP	OG	M	FM	W		
Number of bottles							10	11		11							
Column 1 A	SW	A	13-4337	12/3/13	1200		2	20,21		22,23,24							
Column 1 B	SW	A	4338	12/3/13	1200		2	20,21		22,23,24							
Column 1 C	SW	A	4339	12/3/13	1200		2	20,21		22,23,24							
Column 2 A	SW	A	4340	12/3/13	1200		2	20,21		22,23,24							
Column 2 B	SW	A	4341	12/3/13	1200		2	20,21		22,23,24							
Column 2 C	SW	A	4342	12/3/13	1200		2	20,21		22,23,24							
Column 3 A	SW	A	4343	12/3/13	1200		2	20,21		22,23,24							
Column 3 B	SW	A	4344	12/3/13	1200		2	20,21		22,23,24							
Column 3 C	SW	A	4345	12/3/13	1200		2	20,21		22,23,24							
Influent I	SW	A	4346	12/3/13	1200		2	20,21		22,23,24							
Influent II	SW	A	13-4347	12/3/13	1200			20,21		22,23,24							
DISPOSAL DATE:										12/27/13CH							

COMMENTS:

Relinquished By	Received By	Date	Time
1. [signature]	[signature]	12/4/13	1445
2.			

CUSTODY TRANSFERS

Method of Shipment:

Delivered Directly to Lab: X

Shipped By FedEx: ____ UPS: ____ Other: ____

Received in Cooler: ✓ Y ___N

Temperature: 4 °C

Shipped in Ice: ✓ Y ___N

Ice Present: ✓ Y ___N

pH Checked in Laboratory (< 2 s.u.): ✓ Y ___N

Chlorine Check (< 0.1 mg/l): ___Y ✓ N

*MATRIX: SW=Stormwater SP=Seepage S=Surface Water BF=Baseflow GW=Groundwater BP=Bulk Precipitation G=Grab C=Composite

**ICE PRESERVATION CODES (IPC): A=Transported on ice, ice present when received B=Transported on ice, ice not present when received C=Not transported on ice

Page No. ___

ENVIRONMENTAL RESEARCH & DESIGN, INC. ----- CHAIN-OF-CUSTODY RECORD

3419 Trentwood Blvd., Suite 102 - Orlando, FL 32812 - Phone: (407) 855-9465 - Fax: (407) 826-0419

Client Name: UCF Storm Water Academy	
Address:	
Project Manager:	Phone:
Project Name: BAM	Project Number:
Containers Accepted By: Cassie Pelto	
Samples Collected By: Drew Hood	

						IDENTIFIER CODES											
								F	FP	P	SP	OG	M	FM	W		
						NUMBER OF SAMPLE BOTTLES COLLECTED											
							10	11		11							
Sample I.D.	*Matrix	**IPC	ERD Sample I.D. No.	Date Collected	Time Collected	1-Gallon Plastic (BP)	1-250 ml Plastic	60 mL Plastic (Filtered)	60 mL Plastic (Filtered/ Preserved w/ H_2SO_4)	60 mL Plastic (Preserved w/ H_2SO_4)	250 ml Plastic (SP)	Glass (Preserved w/ HCl)	Metals: UF	250 ml Plastic (Preserved w/ HNO_3) F	Whirlpak	Other ___	Other ___
Column 1 A	SW	A	13-4352	12/6/13	1200		2	20,21		22,23,24							
Column 1 B	SW	A	4353	12/6/13	1200		2	20,21		22,23,24							
Column 1 C	SW	A	4354	12/6/13	1200		2	20,21		22,23,24							
Column 2 A	SW	A	4355	12/6/13	1200		2	20,21		22,23,24							
Column 2 B	SW	A	4356	12/6/13	1200		2	20,21		22,23,24							
Column 2 C	SW	A	4357	12/6/13	1200		2	20,21		22,23,24							
Column 3 A	SW	A	4358	12/6/13	1200		2	20,21		22,23,24							
Column 3 B	SW	A	4359	12/6/13	1200		2	20,21		22,23,24							
Column 3 C	SW	A	4360	12/6/13	1200		2	20,21		22,23,24							
Influent I	SW	A	4361	12/6/13	1200		2	20,21		22,23,24							
Influent II	SW	A	13-4362	12/6/13	1200			20,21		22,23,24							
					DISPOSAL DATE:					12/27/13 ck							

COMMENTS:

CUSTODY TRANSFERS			
Relinquished By	Received By	Date	Time
1. [signature]	[signature]	12/6/13	1445
2.			

Method of Shipment:	Received in Cooler: ✓ Y ___ N	pH Checked in Laboratory (< 2 s.u.): ✓ Y ___ N
Delivered Directly to Lab: X	Temperature: 4 °C	
Shipped By FedEx: ___ UPS: ___ Other: ___	Shipped in Ice: ✓ Y ___ N	Chlorine Check (< 0.1 mg/l): ___ Y ✓ N
	Ice Present: ✓ Y ___ N	

*MATRIX: SW=Stormwater SP=Seepage S=Surface Water BF=Baseflow GW=Groundwater BP=Bulk Precipitation G=Grab C=Composite

**ICE PRESERVATION CODES (IPC): A=Transported on ice, ice present when received B=Transported on ice, ice not present when received C=Not transported on ice

Page No ___

ENVIRONMENTAL RESEARCH & DESIGI .NC. ----- CHAIN-OF-CUSTODY RECORD

3419 Trentwood Blvd., Suite 102 - Orlando, FL 32812 - Phone: (407) 855-9465 - Fax: (407) 826-0419

Client Name: UCF Storm Water Academy

Address:

Project Manager: Phone:

Project Name: BAM Project Number:

Containers Accepted By: Cassie Pelto

Samples Collected By: Drew Hood

Sample I.D.	*Matrix	**IPC	ERD Sample I.D. No.	Date Collected	Time Collected	1- Gallon Plastic (BP)	1-Liter Glass	60 mL Plastic (Filtered)	60 mL Plastic (Filtered/ Preserved w/ H_2SO_4)	60 mL Plastic (Preserved w/ H_2SO_4)	250 ml Plastic (SP)	Glass (Preserved w/ HCl)	Metals: UF	250 ml Plastic (Preserved w/ HNO_3) F	Whirlpak	Other ___	Other ___
IDENTIFIER CODES								F	FP	P	SP	OG	M	FM	W		
NUMBER OF SAMPLE BOTTLES COLLECTED							10	11		11							
Column 1 A	SW	A	B-4379	12/11/13	1030		2	20,21		22,23,24							
Column 1 B	SW	A	4380	12/11/13	1030		2	20,21		22,23,24							
Column 1 C	SW	A	4381	12/11/13	1030		2	20,21		22,23,24							
Column 2 A	SW	A	4382	12/11/13	1030		2	20,21		22,23,24							
Column 2 B	SW	A	4383	12/11/13	1030		2	20,21		22,23,24							
Column 2 C	SW	A	4384	12/11/13	1030		2	20,21		22,23,24							
Column 3 A	SW	A	4385	12/11/13	1030		2	20,21		22,23,24							
Column 3 B	SW	A	4386	12/11/13	1030		2	20,21		22,23,24							
Column 3 C	SW	A	4387	12/11/13	1030		2	20,21		22,23,24							
Influent I	SW	A	4388	12/11/13	1030		2	20,21		22,23,24							
Influent II	SW	A	4389	12/11/13	1030			20,21		22,23,24							
				DISPOSAL DATE:													

COMMENTS:

CUSTODY TRANSFERS			
Relinquished By	Received By	Date	Time
1. [signature]	[signature]	12/11/13	1550
2.			

Method of Shipment:

Delivered Directly to Lab: X

Shipped By FedEx: ___ UPS: ___ Other: ___

Received in Cooler: ✓ Y ___ N

Temperature: 4 °C

Shipped in Ice: ✓ Y ___ N

Ice Present: ✓ Y ___ N

pH Checked in Laboratory (< 2 s.u.): ✓ Y ___ N

Chlorine Check (< 0.1 mg/l): ___ Y ✓ N

*MATRIX: SW=Stormwater SP=Seepage S=Surface Water BF=Baseflow GW=Groundwater BP=Bulk Precipitation G=Grab C=Composite

**ICE PRESERVATION CODES (IPC): A=Transported on ice, ice present when received B=Transported on ice, ice not present when received C=Not transported on ice

Page No. ___

ENVIRONMENTAL RESEARCH & DESIG INC. ----- CHAIN-OF-CUSTODY RECORD

3419 Trentwood Blvd., Suite 102 - Orlando, FL 32812 - Phone: (407) 855-9465 - Fax: (407) 826-0419

Client Name: UCF Storm Water Academy

Address:

Project Manager: Phone:

Project Name: BAM Project Number:

Containers Accepted By: Cassie Pelto

Samples Collected By: Drew Hood

Sample I.D.	*Matrix	**IPC	ERD Sample I.D. No.	Date Collected	Time Collected	1- Gallon Plastic (BP)	1-Liter Glass	60 mL Plastic (Filtered)	60 mL Plastic (Filtered/ Preserved w/ H_2SO_4)	60 mL Plastic (Preserved w/ H_2SO_4)	250 ml Plastic (SP)	Glass (Preserved w/ HCl)	Metals: 250 ml Plastic (Preserved w/ HNO_3) UF	Metals: 250 ml Plastic (Preserved w/ HNO_3) F	Whirlpak	Other ___	Other ___
IDENTIFIER CODES								F	FP	P	SP	OG	M	FM	W		
NUMBER OF SAMPLE BOTTLES COLLECTED							10	11		11							
Column 1 A	SW	A	13-4422	12/13/13	1000		2	20,21		22,23,24							
Column 1 B	SW	A	4423	12/13/13	1000		2	20,21		22,23,24							
Column 1 C	SW	A	4424	12/13/13	1000		2	20,21		22,23,24							
Column 2 A	SW	A	4425	12/13/13	1000		2	20,21		22,23,24							
Column 2 B	SW	A	4426	12/13/13	1000		2	20,21		22,23,24							
Column 2 C	SW	A	4427	12/13/13	1000		2	20,21		22,23,24							
Column 3 A	SW	A	4428	12/13/13	1000		2	20,21		22,23,24							
Column 3 B	SW	A	4429	12/13/13	1000		2	20,21		22,23,24							
Column 3 C	SW	A	4430	12/13/13	1000		2	20,21		22,23,24							
Influent I	SW	A	4431	12/13/13	1000		2	20,21		22,23,24							
Influent II	SW	A	4432	12/13/13	1000			20,21		22,23,24							
					DISPOSAL DATE:												

COMMENTS:

CUSTODY TRANSFERS			
Relinquished By	Received By	Date	Time
1. [signature]	[signature]	12/13/13	1350
2.			

Method of Shipment:

Delivered Directly to Lab: X

Shipped By FedEx: ___ UPS: ___ Other: ___

Received in Cooler: ✓ Y ___ N

Temperature: 4 °C

Shipped in Ice: ✓ Y ___ N

Ice Present: ✓ Y ___ N

pH Checked in Laboratory (< 2 s.u.): ___ Y ___ N

Chlorine Check (< 0.1 mg/l): ___ Y ___ N

*MATRIX: SW=Stormwater SP=Seepage S=Surface Water BF=Baseflow GW=Groundwater BP=Bulk Precipitation G=Grab C=Composite

**ICE PRESERVATION CODES (IPC): A=Transported on ice, ice present when received B=Transported on ice, ice not present when received C=Not transported on ice

APPENDIX C
TOTAL ORGANIC CARBON DATA

Table 43: All TOC Data

Dates	Approximate Flow Duration (hours)	Column BAM #	Column Type	Influent TOC (mg C/L)	Effluent TOC (mg C/L)
10/4/2013	2	1	A	8.82	8.54
10/4/2013	2	1	B	8.82	8.85
10/4/2013	2	1	C	11.36	11.66
10/4/2013	2	2	A	8.82	8.14
10/4/2013	2	2	B	8.82	8.44
10/4/2013	2	2	C	11.36	11.34
10/4/2013	2	3	A	8.82	8.37
10/4/2013	2	3	B	8.82	8.60
10/4/2013	2	3	C	11.36	11.18
10/8/2013	24	1	A	6.14	6.79
10/8/2013	24	1	B	6.14	6.13
10/8/2013	24	1	C	9.75	8.86
10/8/2013	24	2	A	6.14	12.43
10/8/2013	24	2	B	6.14	8.81
10/8/2013	24	2	C	9.75	6.16
10/8/2013	24	3	A	6.14	6.21
10/8/2013	24	3	B	6.14	8.69
10/8/2013	24	3	C	9.75	6.16
10/15/2013	24	1	A	8.01	7.95
10/15/2013	24	1	B	8.01	7.85
10/15/2013	24	1	C	11.10	11.11
10/15/2013	24	2	A	8.01	7.95
10/15/2013	24	2	B	8.01	7.37
10/15/2013	24	2	C	11.10	10.33
10/15/2013	24	3	A	8.01	8.16
10/15/2013	24	3	B	8.01	8.29
10/15/2013	24	3	C	11.10	11.49
10/18/2013	2	1	A	7.67	7.71
10/18/2013	2	1	B	7.67	7.79
10/18/2013	2	1	C	10.53	10.69
10/18/2013	2	2	A	7.67	7.69
10/18/2013	2	2	B	7.67	7.58
10/18/2013	2	2	C	10.53	10.47
10/18/2013	2	3	A	7.67	7.53
10/18/2013	2	3	B	7.67	7.55
10/18/2013	2	3	C	10.53	10.50
10/22/2013	24	1	A	8.53	8.28

Dates	Approximate Flow Duration (hours)	Column BAM #	Column Type	Influent TOC (mg C/L)	Effluent TOC (mg C/L)
10/22/2013	24	1	B	8.53	8.36
10/22/2013	24	1	C	11.48	11.07
10/22/2013	24	2	A	8.53	8.46
10/22/2013	24	2	B	8.53	7.84
10/22/2013	24	2	C	11.48	10.22
10/22/2013	24	3	A	8.53	8.34
10/22/2013	24	3	B	8.53	8.29
10/22/2013	24	3	C	11.48	11.22
10/25/2013	2	1	A	7.30	7.19
10/25/2013	2	1	B	7.30	7.21
10/25/2013	2	1	C	10.10	10.20
10/25/2013	2	2	A	7.30	7.10
10/25/2013	2	2	B	7.30	7.21
10/25/2013	2	2	C	10.10	10.02
10/25/2013	2	3	A	7.30	7.27
10/25/2013	2	3	B	7.30	7.21
10/25/2013	2	3	C	10.10	9.99
10/29/2013	24	1	A	6.85	6.89
10/29/2013	24	1	B	6.85	6.89
10/29/2013	24	1	C	10.05	9.76
10/29/2013	24	2	A	6.85	7.26
10/29/2013	24	2	B	6.85	6.78
10/29/2013	24	2	C	10.05	9.16
10/29/2013	24	3	A	6.85	6.82
10/29/2013	24	3	B	6.85	6.98
10/29/2013	24	3	C	10.05	9.96
11/1/2013	2	1	A	7.50	7.32
11/1/2013	2	1	B	7.50	7.54
11/1/2013	2	1	C	10.70	10.48
11/1/2013	2	2	A	7.50	7.00
11/1/2013	2	2	B	7.50	6.97
11/1/2013	2	2	C	10.70	10.20
11/1/2013	2	3	A	7.50	6.99
11/1/2013	2	3	B	7.50	6.90
11/1/2013	2	3	C	10.70	10.28
11/5/2013	24	1	A	7.21	7.11
11/5/2013	24	1	B	7.21	7.06
11/5/2013	24	1	C	10.16	10.45

Dates	Approximate Flow Duration (hours)	Column BAM #	Column Type	Influent TOC (mg C/L)	Effluent TOC (mg C/L)
11/5/2013	24	2	A	7.21	7.00
11/5/2013	24	2	B	7.21	6.69
11/5/2013	24	2	C	10.16	9.50
11/5/2013	24	3	A	7.21	7.08
11/5/2013	24	3	B	7.21	7.06
11/5/2013	24	3	C	10.16	10.03
11/8/2013	2	1	A	7.58	7.52
11/8/2013	2	1	B	7.58	7.61
11/8/2013	2	1	C	10.29	10.71
11/8/2013	2	2	A	7.58	7.42
11/8/2013	2	2	B	7.58	10.28
11/8/2013	2	2	C	10.29	7.39
11/8/2013	2	3	A	7.58	7.35
11/8/2013	2	3	B	7.58	10.27
11/8/2013	2	3	C	10.29	7.58
11/12/2013	24	1	A	8.11	7.97
11/12/2013	24	1	B	8.11	7.89
11/12/2013	24	1	C	11.00	10.94
11/12/2013	24	2	A	8.11	7.92
11/12/2013	24	2	B	8.11	7.37
11/12/2013	24	2	C	11.00	10.17
11/12/2013	24	3	A	8.11	7.86
11/12/2013	24	3	B	8.11	7.97
11/12/2013	24	3	C	11.00	10.83
11/15/2013	2	1	A	7.51	7.56
11/15/2013	2	1	B	7.51	na
11/15/2013	2	1	C	10.99	10.59
11/15/2013	2	2	A	7.51	7.37
11/15/2013	2	2	B	7.51	7.40
11/15/2013	2	2	C	10.99	10.67
11/15/2013	2	3	A	7.51	7.39
11/15/2013	2	3	B	7.51	7.54
11/15/2013	2	3	C	10.99	10.50
11/19/2013	24	1	A	8.00	8.05
11/19/2013	24	1	B	8.00	8.16
11/19/2013	24	1	C	11.14	10.63
11/19/2013	24	2	A	8.00	7.61
11/19/2013	24	2	B	8.00	8.16

Dates	Approximate Flow Duration (hours)	Column BAM #	Column Type	Influent TOC (mg C/L)	Effluent TOC (mg C/L)
11/19/2013	24	2	C	11.14	10.61
11/19/2013	24	3	A	8.00	8.06
11/19/2013	24	3	B	8.00	8.13
11/19/2013	24	3	C	11.14	10.53
11/22/2013	2	1	A	8.40	8.36
11/22/2013	2	1	B	8.40	8.37
11/22/2013	2	1	C	11.47	11.42
11/22/2013	2	2	A	8.40	8.39
11/22/2013	2	2	B	8.40	8.51
11/22/2013	2	2	C	11.47	11.11
11/22/2013	2	3	A	8.40	8.22
11/22/2013	2	3	B	8.40	8.23
11/22/2013	2	3	C	11.47	11.35
12/3/2013	24	1	A	7.99	8.18
12/3/2013	24	1	B	7.99	8.44
12/3/2013	24	1	C	10.94	11.11
12/3/2013	24	2	A	7.99	8.11
12/3/2013	24	2	B	7.99	8.42
12/3/2013	24	2	C	10.94	11.09
12/3/2013	24	3	A	7.99	8.29
12/3/2013	24	3	B	7.99	8.47
12/3/2013	24	3	C	10.94	11.03
12/6/2013	2	1	A	8.73	8.55
12/6/2013	2	1	B	8.73	8.56
12/6/2013	2	1	C	11.77	11.96
12/6/2013	2	2	A	8.73	8.39
12/6/2013	2	2	B	8.73	8.63
12/6/2013	2	2	C	11.77	11.61
12/6/2013	2	3	A	8.73	8.57
12/6/2013	2	3	B	8.73	8.53
12/6/2013	2	3	C	11.77	11.57
12/11/2013	2	1	A	9.02	8.83
12/11/2013	2	1	B	9.02	8.95
12/11/2013	2	1	C	12.17	12.02
12/11/2013	2	2	A	9.02	8.86
12/11/2013	2	2	B	9.02	8.93
12/11/2013	2	2	C	12.17	11.92
12/11/2013	2	3	A	9.02	8.73

Dates	Approximate Flow Duration (hours)	Column BAM #	Column Type	Influent TOC (mg C/L)	Effluent TOC (mg C/L)
12/11/2013	2	3	B	9.02	8.83
12/11/2013	2	3	C	12.17	11.95
12/12/2013	24	1	A	8.74	8.62
12/12/2013	24	1	B	8.74	8.61
12/12/2013	24	1	C	11.83	11.91
12/12/2013	24	2	A	8.74	8.60
12/12/2013	24	2	B	8.74	8.63
12/12/2013	24	2	C	11.83	11.66
12/12/2013	24	3	A	8.74	8.59
12/12/2013	24	3	B	8.74	8.53
12/12/2013	24	3	C	11.83	11.92

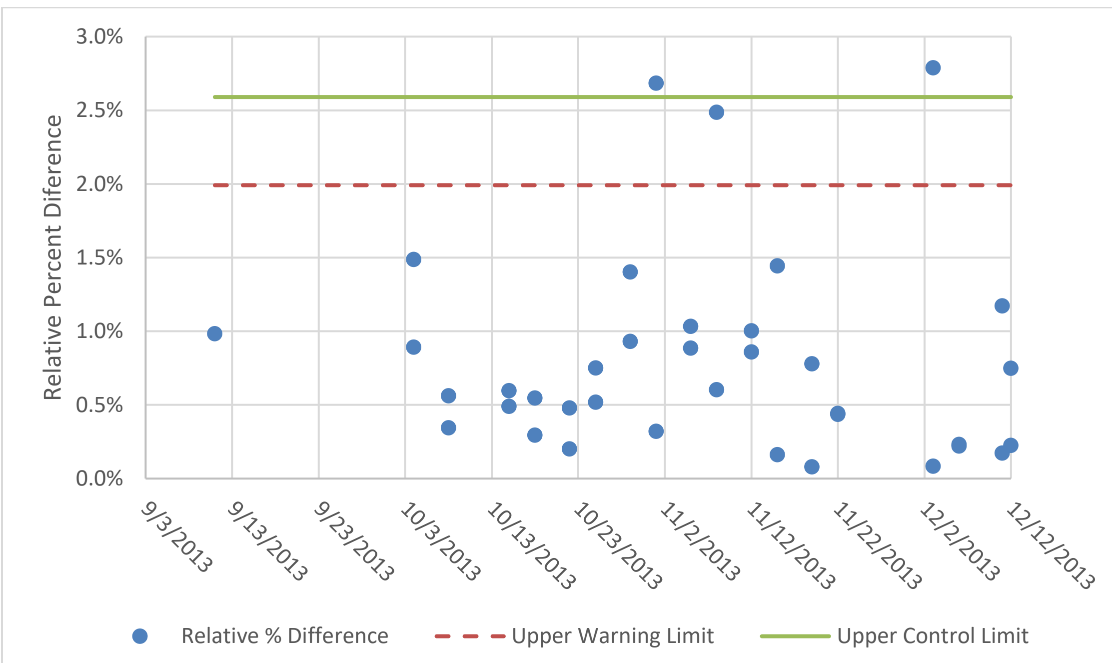


Figure 37: TOC Precision Chart

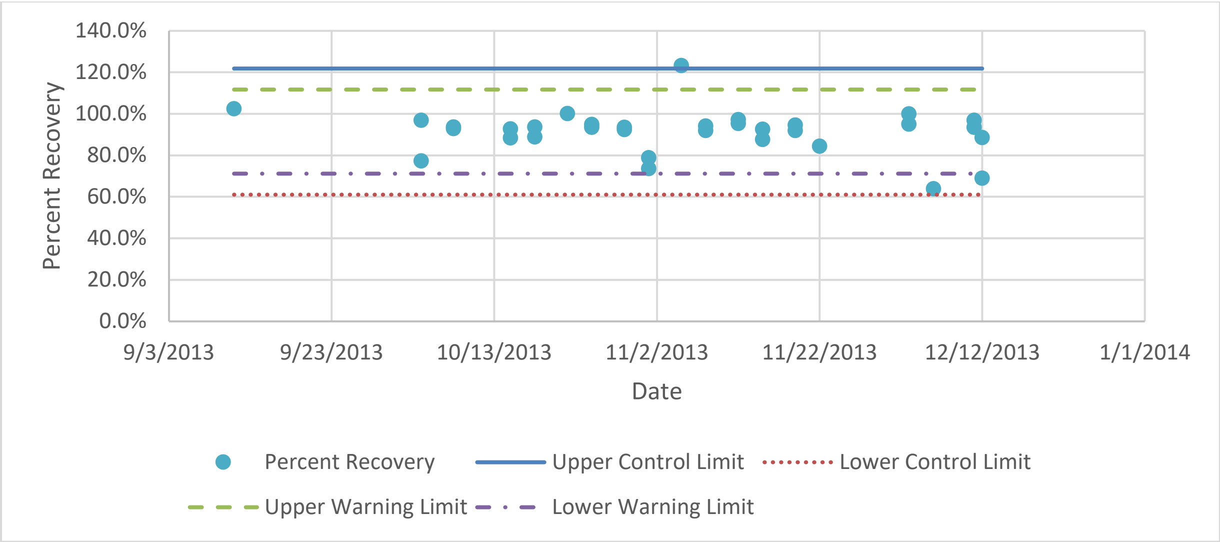


Figure 38: TOC Accuracy Chart

Table 44: TOC for BAM #1, 22-minute EBCT

Columns Run Date	Approximate Flow Duration (hours)	Column Media #	Column Type	Influent TOC (mg C/L)	Effluent TOC (mg C/L)	Δ TOC (mg C/L)
10/4/2013	2	1	A	8.816755903	8.538421554	-0.278334349
10/4/2013	2	1	B	8.816755903	8.852172437	0.035416534
10/18/2013	2	1	A	7.665009757	7.708290339	0.043280582
10/18/2013	2	1	B	7.665009757	7.786236293	0.121226536
10/25/2013	2	1	A	7.295530845	7.188242234	-0.107288611
10/25/2013	2	1	B	7.295530845	7.212791549	-0.082739296
11/1/2013	2	1	A	7.50010637	7.319190139	-0.180916232
11/1/2013	2	1	B	7.50010637	7.540136529	0.040030158
11/8/2013	2	1	A	7.579747505	7.522312759	-0.057434746
11/8/2013	2	1	B	7.579747505	7.613781488	0.034033983
11/15/2013	2	1	A	7.508361715	7.556809793	0.048448078
11/22/2013	2	1	A	8.397310772	8.355872854	-0.041437918
12/6/2013	2	1	A	8.733240297	8.545225465	-0.188014832
12/11/2013	2	1	A	9.022183817	8.826066209	-0.196117608
			median	7.62	7.66	-0.05
			std dev	0.62	0.58	0.11

Note:
Δ = Effluent – Influent, thus a positive Δ indicates an increase and a negative Δ indicates a decrease.

Table 45: TOC for BAM #1, 220-minute EBCT

Columns Run Date	Approximate Flow Duration (hours)	Column Media #	Column Type	Influent TOC (mg C/L)	Effluent TOC (mg C/L)	Δ TOC (mg C/L)
10/8/2013	24	1	A	6.137427701	6.785510258	0.648082557
10/8/2013	24	1	B	6.137427701	6.126262507	-0.011165195
10/15/2013	24	1	A	8.013269036	7.948433426	-0.06483561
10/15/2013	24	1	B	8.013269036	7.851110846	-0.16215819
10/22/2013	24	1	A	8.534420953	8.278819137	-0.255601816
10/22/2013	24	1	B	8.534420953	8.361417597	-0.173003355
10/29/2013	24	1	A	6.847522093	6.885747836	0.038225743
10/29/2013	24	1	B	6.847522093	6.887589831	0.040067738
11/5/2013	24	1	A	7.211934855	7.109150416	-0.102784439
11/5/2013	24	1	B	7.211934855	7.05973925	-0.152195606
11/12/2013	24	1	A	8.111969196	7.965837144	-0.146132052
11/12/2013	24	1	B	8.111969196	7.887255096	-0.2247141
11/19/2013	24	1	A	7.999420891	8.05175327	0.052332378
12/3/2013	24	1	A	7.990569146	8.184944172	0.194375026
12/12/2013	24	1	A	8.73590106	8.621001825	-0.114899234
			median	8.00	7.89	-0.10
			STDDEV	0.81	0.70	0.22

Note:
Δ = Effluent – Influent, thus a positive Δ indicates an increase and a negative Δ indicates a decrease.

Table 46: TOC for BAM #2, 22-minute EBCT

Columns Run Date	Approximate Flow Duration (hours)	Column Media #	Column Type	Influent TOC (mg C/L)	Effluent TOC (mg C/L)	Δ TOC (mg C/L)
10/4/2013	2	2	A	8.816755903	8.143683547	-0.673072356
10/4/2013	2	2	B	8.816755903	8.443229064	-0.373526839
10/18/2013	2	2	A	7.665009757	7.689460595	0.024450838
10/18/2013	2	2	B	7.665009757	7.584026937	-0.08098282
10/25/2013	2	2	A	7.295530845	7.104523396	-0.191007449
10/25/2013	2	2	B	7.295530845	7.210066806	-0.085464039
11/1/2013	2	2	A	7.50010637	6.999618601	-0.50048777
11/1/2013	2	2	B	7.50010637	6.968389517	-0.531716854
11/8/2013	2	2	A	7.579747505	7.417131609	-0.162615896
11/8/2013	2	2	B	7.579747505	10.27527417	2.695526663
11/15/2013	2	2	A	7.508361715	7.374700762	-0.133660953
11/15/2013	2	2	B	7.508361715	7.397454425	-0.11090729
11/22/2013	2	2	A	8.397310772	8.390594096	-0.006716676
12/6/2013	2	2	A	8.733240297	8.39041256	-0.342827737
12/11/2013	2	2	A	9.022183817	8.861444158	-0.160739659
			median	7.58	7.58	-0.16
			std dev	0.61	0.86	0.76

Note:
Δ = Effluent – Influent, thus a positive Δ indicates an increase and a negative Δ indicates a decrease.

Table 47: TOC for BAM #2, 220-minute EBCT

Columns Run Date	Approximate Flow Duration (hours)	Column Media #	Column Type	Influent TOC (mg C/L)	Effluent TOC (mg C/L)	Δ TOC (mg C/L)
10/8/2013	24	2	A	6.137427701	12.43151822	6.294090522
10/8/2013	24	2	B	6.137427701	8.808956898	2.671529197
10/15/2013	24	2	A	8.013269036	7.949693468	-0.063575568
10/15/2013	24	2	B	8.013269036	7.370026878	-0.643242158
10/22/2013	24	2	A	8.534420953	8.455868714	-0.078552238
10/22/2013	24	2	B	8.534420953	7.842249384	-0.692171569
10/29/2013	24	2	A	6.847522093	7.262499979	0.414977886
10/29/2013	24	2	B	6.847522093	6.783133398	-0.064388695
11/5/2013	24	2	A	7.211934855	7.00105285	-0.210882005
11/5/2013	24	2	B	7.211934855	6.687257061	-0.524677794
11/12/2013	24	2	A	8.111969196	7.920919467	-0.191049729
11/12/2013	24	2	B	8.111969196	7.367772618	-0.744196578
11/19/2013	24	2	A	7.999420891	7.60707018	-0.392350711
12/3/2013	24	2	A	7.990569146	8.111648146	0.121079
12/12/2013	24	2	A	8.73590106	8.601088995	-0.134812064
			median	8.00	7.84	-0.13
			STDDEV	0.81	1.33	1.76

Note:
Δ = Effluent – Influent, thus a positive Δ indicates an increase and a negative Δ indicates a decrease.

Table 48: TOC for BAM #3, 22-minute EBCT

Columns Run Date	Approximate Flow Duration (hours)	Column Media #	Column Type	Influent TOC (mg C/L)	Effluent TOC (mg C/L)	Δ TOC (mg C/L)
10/4/2013	2	3	A	8.816755903	8.374178111	-0.442577792
10/4/2013	2	3	B	8.816755903	8.599816967	-0.216938936
10/18/2013	2	3	A	7.665009757	7.531633241	-0.133376515
10/18/2013	2	3	B	7.665009757	7.546319671	-0.118690086
10/25/2013	2	3	A	7.295530845	7.274756556	-0.020774289
10/25/2013	2	3	B	7.295530845	7.214016601	-0.081514244
11/1/2013	2	3	A	7.50010637	6.99332133	-0.50678504
11/1/2013	2	3	B	7.50010637	6.903028364	-0.597078006
11/8/2013	2	3	A	7.579747505	7.353149491	-0.226598014
11/8/2013	2	3	B	7.579747505	10.27377505	2.694027545
11/15/2013	2	3	A	7.508361715	7.393847623	-0.114514092
11/15/2013	2	3	B	7.508361715	7.536786769	0.028425054
11/22/2013	2	3	A	8.397310772	8.224926772	-0.172384
12/6/2013	2	3	A	8.733240297	8.567929038	-0.165311259
12/11/2013	2	3	A	9.022183817	8.731097199	-0.291086618
			median	7.58	7.54	-0.17
			std dev	0.61	0.86	0.75

Note:
Δ = Effluent – Influent, thus a positive Δ indicates an increase and a negative Δ indicates a decrease.

Table 49: TOC for BAM #3, 220-minute EBCT

Columns Run Date	Approximate Flow Duration (hours)	Column Media #	Column Type	Influent TOC (mg C/L)	Effluent TOC (mg C/L)	Δ TOC (mg C/L)
10/8/2013	24	3	A	6.137427701	6.211489505	0.074061804
10/8/2013	24	3	B	6.137427701	8.692368976	2.554941275
10/15/2013	24	3	A	8.013269036	8.1635788	0.150309764
10/15/2013	24	3	B	8.013269036	8.291886023	0.278616987
10/22/2013	24	3	A	8.534420953	8.34403987	-0.190381082
10/22/2013	24	3	B	8.534420953	8.287279191	-0.247141762
10/29/2013	24	3	A	6.847522093	6.819345778	-0.028176315
10/29/2013	24	3	B	6.847522093	6.984210542	0.136688449
11/5/2013	24	3	A	7.211934855	7.080943359	-0.130991496
11/5/2013	24	3	B	7.211934855	7.05770479	-0.154230065
11/12/2013	24	3	A	8.111969196	7.856815772	-0.255153424
11/12/2013	24	3	B	8.111969196	7.967660872	-0.144308324
11/19/2013	24	3	A	7.999420891	8.05954792	0.060127029
12/3/2013	24	3	A	7.990569146	8.288180509	0.297611363
12/12/2013	24	3	A	8.73590106	8.59174383	-0.14415723
			median	8.00	8.06	-0.03
			STDDEV	0.81	0.72	0.67

Note:
Δ = Effluent – Influent, thus a positive Δ indicates an increase and a negative Δ indicates a decrease.

APPENDIX D
DISSOLVED OXYGEN DATA

Table 50: Dissolved Oxygen Data

Columns Run Date	Flow Duration (hours)	Column Media #	Column Type	Influent DO (mg O_2/L)	Effluent DO (mg O_2/L)
7/24/2013	24	1	A	1.8	0.7
7/24/2013	24	1	B	1.8	1.2
7/24/2013	24	1	C	1	1.4
7/24/2013	24	2	A	1.8	0.4
7/24/2013	24	2	B	1.8	0.5
7/24/2013	24	2	C	1	0.6
7/24/2013	24	3	A	1.8	0.5
7/24/2013	24	3	B	1.8	0.6
7/24/2013	24	3	C	1	0.6
7/26/2013	2	1	A	8	2
7/26/2013	2	1	B	8	1.9
7/26/2013	2	1	C	8	3.5
7/26/2013	2	2	A	8	5.2
7/26/2013	2	2	B	8	6.6
7/26/2013	2	2	C	8	7.5
7/26/2013	2	3	A	8	3.6
7/26/2013	2	3	B	8	1.6
7/26/2013	2	3	C	8	5.6
8/1/2013	24	1	A	6.5	1.3
8/1/2013	24	1	B	6.5	1.6
8/1/2013	24	1	C	6.5	1.5
8/1/2013	24	2	A	6.5	1.8
8/1/2013	24	2	B	6.5	1.6
8/1/2013	24	2	C	6.5	4.5
8/1/2013	24	3	A	6.5	0.7
8/1/2013	24	3	B	6.5	0.6
8/1/2013	24	3	C	6.5	1.5
8/5/2013	24	1	A	6.8	2.1
8/5/2013	24	1	B	6.8	2.2
8/5/2013	24	1	C	7.1	2.6
8/5/2013	24	2	A	6.8	1.6
8/5/2013	24	2	B	6.8	1.6
8/5/2013	24	2	C	7.1	4.6
8/5/2013	24	3	A	6.8	1.3
8/5/2013	24	3	B	6.8	1.7
8/5/2013	24	3	C	7.1	2.2
8/13/2013	24	1	A	6.6	1.4

Columns Run Date	Flow Duration (hours)	Column Media #	Column Type	Influent DO (mg O_2/L)	Effluent DO (mg O_2/L)
8/13/2013	24	1	B	6.6	2.3
8/13/2013	24	1	C	6.6	2.1
8/13/2013	24	2	A	6.6	1.6
8/13/2013	24	2	B	6.6	1.8
8/13/2013	24	2	C	6.6	5.1
8/13/2013	24	3	A	6.6	1.1
8/13/2013	24	3	B	6.6	0.8
8/13/2013	24	3	C	6.6	1.45
8/27/2013	24	1	A	na	1.5
8/27/2013	24	1	B	na	3
8/27/2013	24	1	C	na	2.4
8/27/2013	24	2	A	na	1.4
8/27/2013	24	2	B	na	1
8/27/2013	24	2	C	na	4.4
8/27/2013	24	3	A	na	1.3
8/27/2013	24	3	B	na	0.8
8/27/2013	24	3	C	na	1.4
8/30/2013	2	1	A	4.9	3.4
8/30/2013	2	1	B	4.9	2.6
8/30/2013	2	1	C	5.7	2.7
8/30/2013	2	2	A	4.9	2.7
8/30/2013	2	2	B	4.9	3
8/30/2013	2	2	C	5.7	4.7
8/30/2013	2	3	A	4.9	2
8/30/2013	2	3	B	4.9	na
8/30/2013	2	3	C	5.7	3.3
9/3/2013	24	1	A	5.4	2.9
9/3/2013	24	1	B	5.4	2.2
9/3/2013	24	1	C	5.8	2.2
9/3/2013	24	2	A	5.4	2.2
9/3/2013	24	2	B	5.4	1.4
9/3/2013	24	2	C	5.8	4.1
9/3/2013	24	3	A	5.4	1.5
9/3/2013	24	3	B	5.4	1.5
9/3/2013	24	3	C	5.8	1.5
9/27/2013	2	1	A	na	2.2
9/27/2013	2	1	B	na	2.3
9/27/2013	2	1	C	na	4.3
9/27/2013	2	2	A	na	3
9/27/2013	2	2	B	na	3

Columns Run Date	Flow Duration (hours)	Column Media #	Column Type	Influent DO (mg O_2/L)	Effluent DO (mg O_2/L)
9/27/2013	2	2	C	na	4.3
9/27/2013	2	3	A	na	1.8
9/27/2013	2	3	B	na	1.6
9/27/2013	2	3	C	na	3
10/1/2013	24	1	A	na	1.6
10/1/2013	24	1	B	na	1.8
10/1/2013	24	1	C	na	1.3
10/1/2013	24	2	A	na	1
10/1/2013	24	2	B	na	0.7
10/1/2013	24	2	C	na	1.4
10/1/2013	24	3	A	na	0.8
10/1/2013	24	3	B	na	1.3
10/1/2013	24	3	C	na	1.1
10/4/2013	2	1	A	na	2.1
10/4/2013	2	1	B	na	1.5
10/4/2013	2	1	C	na	3.1
10/4/2013	2	2	A	na	2.6
10/4/2013	2	2	B	na	3.1
10/4/2013	2	2	C	na	4.7
10/4/2013	2	3	A	na	1.7
10/4/2013	2	3	B	na	1.9
10/4/2013	2	3	C	na	3.2
10/8/2013	24	1	A	5	2
10/8/2013	24	1	B	5	1.2
10/8/2013	24	1	C	5	1.9
10/8/2013	24	2	A	5	1
10/8/2013	24	2	B	5	1
10/8/2013	24	2	C	5	2.5
10/8/2013	24	3	A	5	1.2
10/8/2013	24	3	B	5	1
10/8/2013	24	3	C	5	1
10/15/2013	24	1	A	4.6	1.2
10/15/2013	24	1	B	4.6	1.9
10/15/2013	24	1	C	5.5	3.3
10/15/2013	24	2	A	4.6	0.5
10/15/2013	24	2	B	4.6	0.4
10/15/2013	24	2	C	5.5	0.7
10/15/2013	24	3	A	4.6	0.5
10/15/2013	24	3	B	4.6	0.5
10/15/2013	24	3	C	5.5	0.5

Columns Run Date	Flow Duration (hours)	Column Media #	Column Type	Influent DO (mg O_2/L)	Effluent DO (mg O_2/L)
10/18/2013	2	1	A	na	2.9
10/18/2013	2	1	B	na	1.5
10/18/2013	2	1	C	na	3.3
10/18/2013	2	2	A	na	2.8
10/18/2013	2	2	B	na	2.7
10/18/2013	2	2	C	na	4.4
10/18/2013	2	3	A	na	2.1
10/18/2013	2	3	B	na	1.8
10/18/2013	2	3	C	na	2.7
10/22/2013	24	1	A	4.9	1.2
10/22/2013	24	1	B	4.9	0.7
10/22/2013	24	1	C	5	1.6
10/22/2013	24	2	A	4.9	0.7
10/22/2013	24	2	B	4.9	0.7
10/22/2013	24	2	C	5	1.6
10/22/2013	24	3	A	4.9	0.7
10/22/2013	24	3	B	4.9	0.7
10/22/2013	24	3	C	5	0.7
10/25/2013	2	1	A	4.6	1.5
10/25/2013	2	1	B	4.6	1.6
10/25/2013	2	1	C	5.5	3.1
10/25/2013	2	2	A	4.6	2.1
10/25/2013	2	2	B	4.6	2.6
10/25/2013	2	2	C	5.5	4.7
10/25/2013	2	3	A	4.6	1.5
10/25/2013	2	3	B	4.6	1.6
10/25/2013	2	3	C	5.5	3.5
10/29/2013	24	1	A	5.7	0.8
10/29/2013	24	1	B	5.7	1.7
10/29/2013	24	1	C	6	1.8
10/29/2013	24	2	A	5.7	1
10/29/2013	24	2	B	5.7	0.8
10/29/2013	24	2	C	6	2.8
10/29/2013	24	3	A	5.7	0.7
10/29/2013	24	3	B	5.7	0.7
10/29/2013	24	3	C	6	1
11/1/2013	2	1	A	4.5	1.8
11/1/2013	2	1	B	4.5	1.6
11/1/2013	2	1	C	5.3	3.11
11/1/2013	2	2	A	4.5	2.6

Columns Run Date	Flow Duration (hours)	Column Media #	Column Type	Influent DO (mg O_2/L)	Effluent DO (mg O_2/L)
11/1/2013	2	2	B	4.5	3
11/1/2013	2	2	C	5.3	4.5
11/1/2013	2	3	A	4.5	1.8
11/1/2013	2	3	B	4.5	1.9
11/1/2013	2	3	C	5.3	3.4
11/5/2013	24	1	A	5	1.1
11/5/2013	24	1	B	5	1.5
11/5/2013	24	1	C	5.6	1.6
11/5/2013	24	2	A	5	0.7
11/5/2013	24	2	B	5	0.7
11/5/2013	24	2	C	5.6	3.5
11/5/2013	24	3	A	5	0.6
11/5/2013	24	3	B	5	0.5
11/5/2013	24	3	C	5.6	0.6
11/8/2013	2	1	A	5.7	3
11/8/2013	2	1	B	5.7	2.8
11/8/2013	2	1	C	6.5	5.2
11/8/2013	2	2	A	5.7	3.9
11/8/2013	2	2	B	5.7	3.8
11/8/2013	2	2	C	6.5	5.9
11/8/2013	2	3	A	5.7	2.5
11/8/2013	2	3	B	5.7	3.1
11/8/2013	2	3	C	6.5	4.8
11/12/2013	24	1	A	6	0.7
11/12/2013	24	1	B	6	1.7
11/12/2013	24	1	C	5.7	1.1
11/12/2013	24	2	A	6	1
11/12/2013	24	2	B	6	0.5
11/12/2013	24	2	C	5.7	3.6
11/12/2013	24	3	A	6	0.4
11/12/2013	24	3	B	6	0.4
11/12/2013	24	3	C	5.7	0.8
11/15/2013	2	1	A	4.7	1.9
11/15/2013	2	1	B	4.7	na
11/15/2013	2	1	C	5.1	2.7
11/15/2013	2	2	A	4.7	3
11/15/2013	2	2	B	4.7	3.2
11/15/2013	2	2	C	5.1	5.2
11/15/2013	2	3	A	4.7	2.4
11/15/2013	2	3	B	4.7	2.1

Columns Run Date	Flow Duration (hours)	Column Media #	Column Type	Influent DO (mg O_2/L)	Effluent DO (mg O_2/L)
11/15/2013	2	3	C	5.1	3.7
11/19/2013	24	1	A	5.7	1
11/19/2013	24	1	C	6.3	1.1
11/19/2013	24	2	A	5.7	1.1
11/19/2013	24	2	C	6.3	5.1
11/19/2013	24	3	A	5.7	1.3
11/19/2013	24	3	C	6.3	1.4
11/22/2013	2	1	A	6.3	2.9
11/22/2013	2	1	C	6.4	4
11/22/2013	2	2	A	6.3	3.3
11/22/2013	2	2	C	6.4	5.4
11/22/2013	2	3	A	6.3	1.9
11/22/2013	2	3	C	6.4	3.9
12/3/2013	24	1	A	6.7	1.5
12/3/2013	24	1	C	6.6	2.2
12/3/2013	24	2	A	6.7	1.6
12/3/2013	24	2	C	6.6	5
12/3/2013	24	3	A	6.7	1.1
12/3/2013	24	3	C	6.6	1.4
12/6/2013	2	1	A	na	3.1
12/6/2013	2	1	C	na	4.3
12/6/2013	2	2	A	na	3.4
12/6/2013	2	2	C	na	5.8
12/6/2013	2	3	A	na	2.4
12/6/2013	2	3	C	na	4.5
12/11/2013	2	1	A	6.2	4
12/11/2013	2	1	C	6.9	5.5
12/11/2013	2	2	A	6.2	4.1
12/11/2013	2	2	C	6.9	6.4
12/11/2013	2	3	A	6.2	2.9
12/11/2013	2	3	C	6.9	5.3
12/12/2013	24	1	A	6.2	1.6
12/12/2013	24	1	C	6.6	2.6
12/12/2013	24	2	A	6.2	2.2
12/12/2013	24	2	C	6.6	5.6
12/12/2013	24	3	A	6.2	1.9
12/12/2013	24	3	C	6.6	1.8

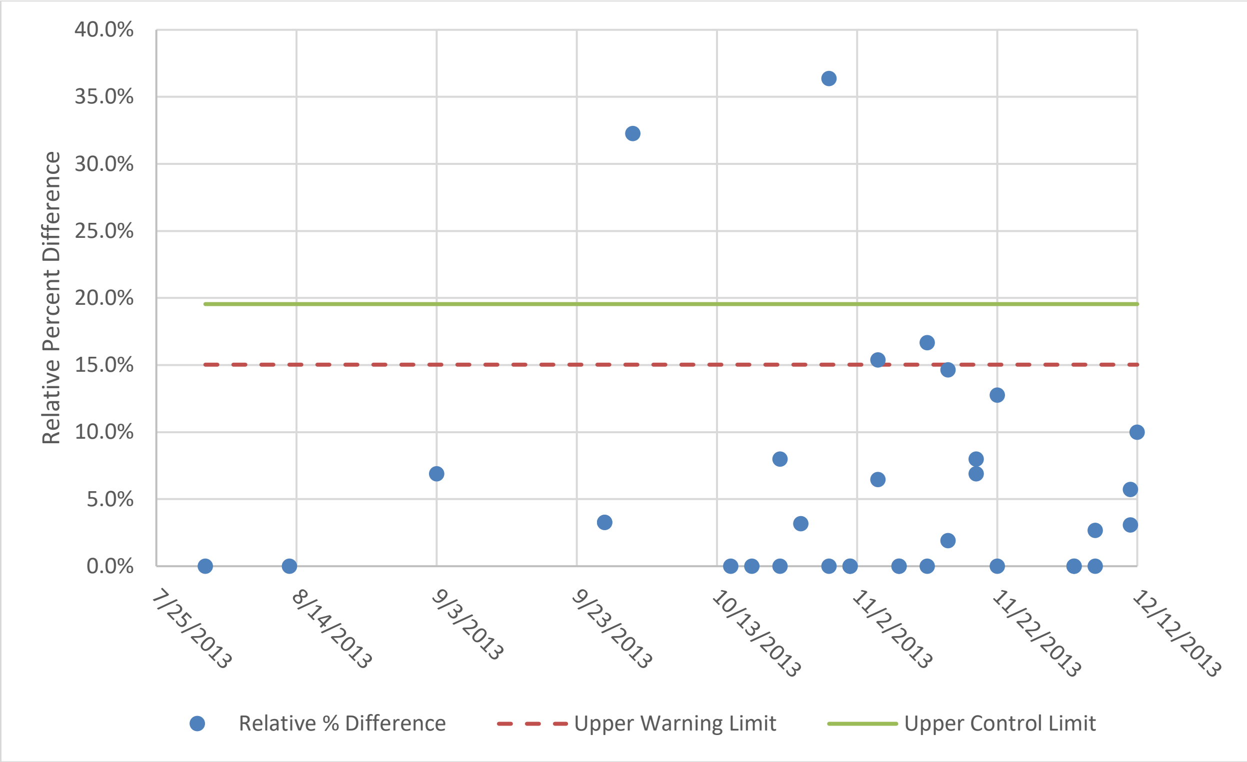


Figure 39: DO Precision Control Chart

Table 51: Dissolved Oxygen for BAM #1, 22-minute EBCT

Approximate Flow Duration (hours)	Columns Run Date	Column Media #	Column Type	UCF Analyzed: Influent DO (mg O2/L)	UCF Analyzed: Effluent DO (mg O2/L)	Measured DO consumption (mg O_2/L)
2	10/25/2013	1	A	4.6	1.5	3.1
2	10/25/2013	1	B	4.6	1.6	3
2	11/1/2013	1	A	4.5	1.8	2.7
2	11/1/2013	1	B	4.5	1.6	2.9
2	11/8/2013	1	A	5.7	3	2.7
2	11/8/2013	1	B	5.7	2.8	2.9
2	11/15/2013	1	A	4.7	1.9	2.8
2	11/22/2013	1	A	6.3	2.9	3.4
2	12/11/2013	1	A	6.2	4	2.2
			median	4.70	1.90	2.90

Table 52: Dissolved Oxygen for BAM #2, 22-minute EBCT

Approximate Flow Duration (hours)	Columns Run Date	Column Media #	Column Type	UCF Analyzed: Influent DO (mg O2/L)	UCF Analyzed: Effluent DO (mg O2/L)	Measured DO consumption (mg O_2/L)
2	10/25/2013	2	A	4.6	2.1	2.5
2	10/25/2013	2	B	4.6	2.6	2
2	11/1/2013	2	A	4.5	2.6	1.9
2	11/1/2013	2	B	4.5	3	1.5
2	11/8/2013	2	A	5.7	3.9	1.8
2	11/8/2013	2	B	5.7	3.8	1.9
2	11/15/2013	2	A	4.7	3	1.7
2	11/15/2013	2	B	4.7	3.2	1.5
2	11/22/2013	2	A	6.3	3.3	3
2	12/11/2013	2	A	6.2	4.1	2.1
			median	4.70	3.10	1.90

Table 53: Dissolved Oxygen for BAM #3, 22-minute EBCT

Approximate Flow Duration (hours)	Columns Run Date	Column Media #	Column Type	UCF Analyzed: Influent DO (mg O2/L)	UCF Analyzed: Effluent DO (mg O2/L)	Measured DO consumption (mg O_2/L)
2	10/25/2013	3	A	4.6	1.5	3.1
2	10/25/2013	3	B	4.6	1.6	3
2	11/1/2013	3	A	4.5	1.8	2.7
2	11/1/2013	3	B	4.5	1.9	2.6
2	11/8/2013	3	A	5.7	2.5	3.2
2	11/8/2013	3	B	5.7	3.1	2.6
2	11/15/2013	3	A	4.7	2.4	2.3
2	11/15/2013	3	B	4.7	2.1	2.6
2	11/22/2013	3	A	6.3	1.9	4.4
2	12/11/2013	3	A	6.2	2.9	3.3
			median	4.7	2.00	2.85

Table 54: Dissolved Oxygen for BAM #1, 220-minute EBCT

Approximate Flow Duration (hours)	Columns Run Date	Column Media #	Column Type	UCF Analyzed: Influent DO (mg O2/L)	UCF Analyzed: Effluent DO (mg O2/L)	Measured DO consumption (mg O_2/L)
24	10/8/2013	1	A	5.00	2.00	3.00
24	10/8/2013	1	B	5.00	1.20	3.80
24	10/15/2013	1	A	4.60	1.20	3.40
24	10/15/2013	1	B	4.60	1.90	2.70
24	10/22/2013	1	A	4.90	1.20	3.70
24	10/22/2013	1	B	4.90	0.70	4.20
24	10/29/2013	1	A	5.70	0.80	4.90
24	10/29/2013	1	B	5.70	1.70	4.00
24	11/5/2013	1	A	5.00	1.10	3.90
24	11/5/2013	1	B	5.00	1.50	3.50
24	11/12/2013	1	A	6.00	0.70	5.30
24	11/12/2013	1	B	6.00	1.70	4.30
24	11/19/2013	1	A	5.70	1.00	4.70
24	12/3/2013	1	A	6.70	1.50	5.20
24	12/12/2013	1	A	6.20	1.60	4.60
			median	5.00	1.20	4.00

Table 55: Dissolved Oxygen for BAM #2, 220-minute EBCT

Approximate Flow Duration (hours)	Columns Run Date	Column Media #	Column Type	UCF Analyzed: Influent DO (mg O2/L)	UCF Analyzed: Effluent DO (mg O2/L)	Measured DO consumption (mg O_2/L)
24	10/8/2013	2	A	5.00	1.00	4.00
24	10/8/2013	2	B	5.00	1.00	4.00
24	10/15/2013	2	A	4.60	0.50	4.10
24	10/15/2013	2	B	4.60	0.40	4.20
24	10/22/2013	2	A	4.90	0.70	4.20
24	10/22/2013	2	B	4.90	0.70	4.20
24	10/29/2013	2	A	5.70	1.00	4.70
24	10/29/2013	2	B	5.70	0.80	4.90
24	11/5/2013	2	A	5.00	0.70	4.30
24	11/5/2013	2	B	5.00	0.70	4.30
24	11/12/2013	2	A	6.00	1.00	5.00
24	11/12/2013	2	B	6.00	0.50	5.50
24	11/19/2013	2	A	5.70	1.10	4.60
24	12/3/2013	2	A	6.70	1.60	5.10
24	12/12/2013	2	A	6.20	2.20	4.00
			median	5.00	0.80	4.30

Table 56: Dissolved Oxygen for BAM #3, 220-minute EBCT

Approximate Flow Duration (hours)	Columns Run Date	Column Media #	Column Type	UCF Analyzed: Influent DO (mg O2/L)	UCF Analyzed: Effluent DO (mg O2/L)	Measured DO consumption (mg O_2/L)
24	**10/8/2013**	3	**A**	5	1.2	3.8
24	**10/8/2013**	3	**B**	5	1	4
24	**10/15/2013**	3	**A**	4.6	0.5	4.1
24	**10/15/2013**	3	**B**	4.6	0.5	4.1
24	**10/22/2013**	3	**A**	4.9	0.7	4.2
24	**10/22/2013**	3	**B**	4.9	0.7	4.2
24	**10/29/2013**	3	**A**	5.7	0.7	5
24	**10/29/2013**	3	**B**	5.7	0.7	5
24	**11/5/2013**	3	**A**	5	0.6	4.4
24	**11/5/2013**	3	**B**	5	0.5	4.5
24	**11/12/2013**	3	**A**	6	0.4	5.6
24	**11/12/2013**	3	**B**	6	0.4	5.6
24	**11/19/2013**	3	**A**	5.7	1.3	4.4
24	**12/3/2013**	3	**A**	6.7	1.1	5.6
24	**12/12/2013**	3	**A**	6.2	1.9	4.3
			median	5.00	0.70	4.40

APPENDIX E
pH DATA

Table 57: pH Data

Columns Run Date	Flow Duration (hours)	Column BAM #	Column Type	UCF Analyzed: Influent pH	UCF Analyzed: Effluent pH
4/18/2013	2	1	A	7.19	7.50
4/18/2013	2	1	B	7.19	7.44
4/18/2013	2	1	C	7.40	7.41
4/18/2013	2	2	A	7.19	7.29
4/18/2013	2	2	B	7.19	7.12
4/18/2013	2	2	C	7.40	7.28
4/18/2013	2	3	A	7.19	7.65
4/18/2013	2	3	B	7.19	7.57
4/18/2013	2	3	C	7.40	7.54
4/25/2013	2	1	A	6.75	7.40
4/25/2013	2	1	B	6.75	7.35
4/25/2013	2	1	C	6.97	7.47
4/25/2013	2	2	A	6.75	6.76
4/25/2013	2	2	B	6.75	7.21
4/25/2013	2	2	C	6.97	6.85
4/25/2013	2	3	A	6.75	7.54
4/25/2013	2	3	B	6.75	7.64
4/25/2013	2	3	C	6.97	7.63
4/30/2013	2	1	A	6.97	7.08
4/30/2013	2	1	B	6.97	7.11
4/30/2013	2	1	C	7.29	7.14
4/30/2013	2	2	A	6.97	6.83
4/30/2013	2	2	B	6.97	6.92
4/30/2013	2	2	C	7.29	6.99
4/30/2013	2	3	A	6.97	7.12
4/30/2013	2	3	B	6.97	7.11
4/30/2013	2	3	C	7.29	7.15
5/1/2013	2	1	A	6.99	7.32
5/1/2013	2	1	B	6.99	7.51
5/1/2013	2	1	C	6.99	7.38
5/1/2013	2	2	A	6.99	7.34
5/1/2013	2	2	B	6.99	7.33
5/1/2013	2	2	C	6.99	7.53
5/1/2013	2	3	A	6.99	7.53
5/1/2013	2	3	B	6.99	7.48
5/1/2013	2	3	C	6.99	7.46
5/7/2013	2	1	A	7.21	7.28
5/7/2013	2	1	B	7.21	7.37

Columns Run Date	Flow Duration (hours)	Column BAM #	Column Type	UCF Analyzed: Influent pH	UCF Analyzed: Effluent pH
5/7/2013	2	1	C	7.21	7.35
5/7/2013	2	2	A	7.21	7.36
5/7/2013	2	2	B	7.21	7.12
5/7/2013	2	2	C	7.21	7.33
5/7/2013	2	3	A	7.21	7.27
5/7/2013	2	3	B	7.21	7.10
5/7/2013	2	3	C	7.21	7.13
6/6/2013	2	1	A	7.39	7.44
6/6/2013	2	1	B	7.39	7.47
6/6/2013	2	1	C	7.35	7.44
6/6/2013	2	2	A	7.39	7.36
6/6/2013	2	2	B	7.39	7.36
6/6/2013	2	2	C	7.35	7.45
6/6/2013	2	3	A	7.39	7.56
6/6/2013	2	3	B	7.39	7.59
6/6/2013	2	3	C	7.35	7.60
6/12/2013	2	1	A	7.09	7.31
6/12/2013	2	1	B	7.09	7.35
6/12/2013	2	1	C	7.02	7.38
6/12/2013	2	2	A	7.09	7.57
6/12/2013	2	2	B	7.09	7.28
6/12/2013	2	2	C	7.02	7.18
6/12/2013	2	3	A	7.09	7.49
6/12/2013	2	3	B	7.09	7.47
6/12/2013	2	3	C	7.02	7.30
7/24/2013	24	1	A	6.53	7.15
7/24/2013	24	1	B	6.53	6.95
7/24/2013	24	1	C	6.58	7.05
7/24/2013	24	2	A	6.53	7.01
7/24/2013	24	2	B	6.53	6.92
7/24/2013	24	2	C	6.58	7.10
7/24/2013	24	3	A	6.53	7.60
7/24/2013	24	3	B	6.53	7.63
7/24/2013	24	3	C	6.58	7.46
7/26/2013	2	1	A	6.83	7.20
7/26/2013	2	1	B	6.83	7.07
7/26/2013	2	1	C	6.98	6.83
7/26/2013	2	2	A	6.83	7.23
7/26/2013	2	2	B	6.83	7.13

Columns Run Date	Flow Duration (hours)	Column BAM #	Column Type	UCF Analyzed: Influent pH	UCF Analyzed: Effluent pH
7/26/2013	2	2	C	6.98	7.67
7/26/2013	2	3	A	6.83	7.62
7/26/2013	2	3	B	6.83	7.67
7/26/2013	2	3	C	6.98	7.51
7/31/2013	2	1	A	7.28	7.22
7/31/2013	2	1	B	7.28	7.40
7/31/2013	2	1	C	7.33	7.43
7/31/2013	2	2	A	7.28	7.50
7/31/2013	2	2	B	7.28	7.13
7/31/2013	2	2	C	7.33	7.54
7/31/2013	2	3	A	7.28	7.74
7/31/2013	2	3	B	7.28	7.30
7/31/2013	2	3	C	7.33	7.69
8/1/2013	24	1	A	7.17	7.44
8/1/2013	24	1	B	7.17	7.93
8/1/2013	24	1	C	7.21	7.32
8/1/2013	24	2	A	7.17	7.28
8/1/2013	24	2	B	7.17	7.25
8/1/2013	24	2	C	7.21	7.40
8/1/2013	24	3	A	7.17	8.03
8/1/2013	24	3	B	7.17	7.65
8/1/2013	24	3	C	7.21	7.67
8/5/2013	24	1	A	7.05	7.42
8/5/2013	24	1	B	7.05	7.62
8/5/2013	24	1	C	7.19	7.18
8/5/2013	24	2	A	7.05	7.14
8/5/2013	24	2	B	7.05	7.13
8/5/2013	24	2	C	7.19	7.31
8/5/2013	24	3	A	7.05	7.83
8/5/2013	24	3	B	7.05	7.37
8/5/2013	24	3	C	7.19	7.08
8/7/2013	2	1	A	6.70	7.30
8/7/2013	2	1	B	6.70	7.33
8/7/2013	2	1	C	6.95	7.28
8/7/2013	2	2	A	6.70	7.30
8/7/2013	2	2	B	6.70	7.31
8/7/2013	2	2	C	6.95	7.46
8/7/2013	2	3	A	6.70	7.69
8/7/2013	2	3	B	6.70	7.40

Columns Run Date	Flow Duration (hours)	Column BAM #	Column Type	UCF Analyzed: Influent pH	UCF Analyzed: Effluent pH
8/7/2013	2	3	C	6.95	7.63
8/13/2013	24	1	A	7.25	7.09
8/13/2013	24	1	B	7.25	7.62
8/13/2013	24	1	C	7.25	7.80
8/13/2013	24	2	A	7.25	7.19
8/13/2013	24	2	B	7.25	7.18
8/13/2013	24	2	C	7.25	7.13
8/13/2013	24	3	A	7.25	7.32
8/13/2013	24	3	B	7.25	7.37
8/13/2013	24	3	C	7.25	7.49
8/15/2013	2	1	A	7.21	7.80
8/15/2013	2	1	B	7.21	7.67
8/15/2013	2	1	C	7.24	7.21
8/15/2013	2	2	A	7.21	7.19
8/15/2013	2	2	B	7.21	7.63
8/15/2013	2	2	C	7.24	7.30
8/15/2013	2	3	A	7.21	7.73
8/15/2013	2	3	B	7.21	7.62
8/15/2013	2	3	C	7.24	7.58
8/27/2013	24	1	A	7.11	7.22
8/27/2013	24	1	B	7.11	7.50
8/27/2013	24	1	C	7.21	7.11
8/27/2013	24	2	A	7.11	7.12
8/27/2013	24	2	B	7.11	7.23
8/27/2013	24	2	C	7.21	7.37
8/27/2013	24	3	A	7.11	7.72
8/27/2013	24	3	B	7.11	7.65
8/27/2013	24	3	C	7.21	7.65
8/30/2013	2	1	A	7.15	6.96
8/30/2013	2	1	B	7.15	7.19
8/30/2013	2	1	C	7.22	7.21
8/30/2013	2	2	A	7.15	7.08
8/30/2013	2	2	B	7.15	7.28
8/30/2013	2	2	C	7.22	7.32
8/30/2013	2	3	A	7.15	7.45
8/30/2013	2	3	B	7.15	na
8/30/2013	2	3	C	7.22	7.47
9/3/2013	24	1	A	6.78	7.28
9/3/2013	24	1	B	6.78	7.47

Columns Run Date	Flow Duration (hours)	Column BAM #	Column Type	UCF Analyzed: Influent pH	UCF Analyzed: Effluent pH
9/3/2013	24	1	C	6.95	7.05
9/3/2013	24	2	A	6.78	7.08
9/3/2013	24	2	B	6.78	6.85
9/3/2013	24	2	C	6.95	7.20
9/3/2013	24	3	A	6.78	7.69
9/3/2013	24	3	B	6.78	7.53
9/3/2013	24	3	C	6.95	7.50
9/24/2013	24	1	A	7.10	7.29
9/24/2013	24	1	B	7.10	6.94
9/24/2013	24	1	C	7.18	6.97
9/24/2013	24	2	A	7.10	7.29
9/24/2013	24	2	B	7.10	7.12
9/24/2013	24	2	C	7.18	7.32
9/24/2013	24	3	A	7.10	7.47
9/24/2013	24	3	B	7.10	7.49
9/24/2013	24	3	C	7.18	7.58
9/27/2013	2	1	A	6.40	6.72
9/27/2013	2	1	B	6.40	6.78
9/27/2013	2	1	C	na	6.74
9/27/2013	2	2	A	6.40	6.92
9/27/2013	2	2	B	6.40	6.83
9/27/2013	2	2	C	na	6.78
9/27/2013	2	3	A	6.40	7.14
9/27/2013	2	3	B	6.40	7.13
9/27/2013	2	3	C	na	7.12
10/1/2013	24	1	A	6.99	7.14
10/1/2013	24	1	B	6.99	6.94
10/1/2013	24	1	C	6.92	6.82
10/1/2013	24	2	A	6.99	7.00
10/1/2013	24	2	B	6.99	6.83
10/1/2013	24	2	C	6.92	7.28
10/1/2013	24	3	A	6.99	7.42
10/1/2013	24	3	B	6.99	7.44
10/1/2013	24	3	C	6.92	7.42
10/4/2013	2	1	A	6.76	7.08
10/4/2013	2	1	B	6.76	7.04
10/4/2013	2	1	C	6.81	6.79
10/4/2013	2	2	A	6.76	6.87
10/4/2013	2	2	B	6.76	7.60

Columns Run Date	Flow Duration (hours)	Column BAM #	Column Type	UCF Analyzed: Influent pH	UCF Analyzed: Effluent pH
10/4/2013	2	2	C	6.81	7.23
10/4/2013	2	3	A	6.76	7.29
10/4/2013	2	3	B	6.76	7.24
10/4/2013	2	3	C	6.81	7.19
10/8/2013	24	1	A	7.18	7.60
10/8/2013	24	1	B	7.18	7.44
10/8/2013	24	1	C	7.19	7.21
10/8/2013	24	2	A	7.18	7.40
10/8/2013	24	2	B	7.18	7.34
10/8/2013	24	2	C	7.19	7.41
10/8/2013	24	3	A	7.18	7.86
10/8/2013	24	3	B	7.18	7.70
10/8/2013	24	3	C	7.19	7.64
10/15/2013	24	1	A	6.81	7.00
10/15/2013	24	1	B	6.81	6.94
10/15/2013	24	1	C	6.82	7.09
10/15/2013	24	2	A	6.81	6.98
10/15/2013	24	2	B	6.81	6.71
10/15/2013	24	2	C	6.82	7.13
10/15/2013	24	3	A	6.81	7.45
10/15/2013	24	3	B	6.81	7.46
10/15/2013	24	3	C	6.82	7.33
10/18/2013	2	1	A	na	6.90
10/18/2013	2	1	B	na	6.89
10/18/2013	2	1	C	na	6.97
10/18/2013	2	2	A	na	7.01
10/18/2013	2	2	B	na	7.09
10/18/2013	2	2	C	na	7.25
10/18/2013	2	3	A	na	7.39
10/18/2013	2	3	B	na	7.57
10/18/2013	2	3	C	na	7.43
10/22/2013	24	1	A	6.71	7.19
10/22/2013	24	1	B	6.71	7.01
10/22/2013	24	1	C	6.72	6.73
10/22/2013	24	2	A	6.71	6.96
10/22/2013	24	2	B	6.71	6.86
10/22/2013	24	2	C	6.72	7.11
10/22/2013	24	3	A	6.71	7.34
10/22/2013	24	3	B	6.71	7.30

Columns Run Date	Flow Duration (hours)	Column BAM #	Column Type	UCF Analyzed: Influent pH	UCF Analyzed: Effluent pH
10/22/2013	24	3	C	6.72	7.38
10/25/2013	2	1	A	6.91	7.27
10/25/2013	2	1	B	6.91	7.14
10/25/2013	2	1	C	6.90	6.73
10/25/2013	2	2	A	6.91	7.14
10/25/2013	2	2	B	6.91	7.00
10/25/2013	2	2	C	6.90	7.28
10/25/2013	2	3	A	6.91	7.41
10/25/2013	2	3	B	6.91	7.44
10/25/2013	2	3	C	6.90	7.41
10/29/2013	24	1	A	6.86	7.08
10/29/2013	24	1	B	6.86	7.06
10/29/2013	24	1	C	7.08	6.79
10/29/2013	24	2	A	6.86	7.03
10/29/2013	24	2	B	6.86	6.94
10/29/2013	24	2	C	7.08	7.19
10/29/2013	24	3	A	6.86	7.53
10/29/2013	24	3	B	6.86	7.53
10/29/2013	24	3	C	7.08	7.57
11/1/2013	2	1	A	7.31	7.30
11/1/2013	2	1	B	7.31	6.95
11/1/2013	2	1	C	7.44	7.58
11/1/2013	2	2	A	7.31	7.57
11/1/2013	2	2	B	7.31	7.50
11/1/2013	2	2	C	7.44	7.69
11/1/2013	2	3	A	7.31	7.73
11/1/2013	2	3	B	7.31	7.77
11/1/2013	2	3	C	7.44	7.77
11/5/2013	24	1	A	6.99	6.91
11/5/2013	24	1	B	6.99	6.91
11/5/2013	24	1	C	7.23	6.87
11/5/2013	24	2	A	6.99	7.11
11/5/2013	24	2	B	6.99	6.98
11/5/2013	24	2	C	7.23	7.20
11/5/2013	24	3	A	6.99	7.41
11/5/2013	24	3	B	6.99	7.54
11/5/2013	24	3	C	7.23	7.58
11/8/2013	2	1	A	7.08	6.96
11/8/2013	2	1	B	7.08	7.05

Columns Run Date	Flow Duration (hours)	Column BAM #	Column Type	UCF Analyzed: Influent pH	UCF Analyzed: Effluent pH
11/8/2013	2	1	C	7.12	6.81
11/8/2013	2	2	A	7.08	7.20
11/8/2013	2	2	B	7.08	7.07
11/8/2013	2	2	C	7.12	7.34
11/8/2013	2	3	A	7.08	7.36
11/8/2013	2	3	B	7.08	7.37
11/8/2013	2	3	C	7.12	7.41
11/12/2013	24	1	A	6.84	6.90
11/12/2013	24	1	B	6.84	6.69
11/12/2013	24	1	C	6.62	6.79
11/12/2013	24	2	A	6.84	6.79
11/12/2013	24	2	B	6.84	6.65
11/12/2013	24	2	C	6.62	7.03
11/12/2013	24	3	A	6.84	7.18
11/12/2013	24	3	B	6.84	7.18
11/12/2013	24	3	C	6.62	7.32
11/15/2013	2	1	A	7.12	7.39
11/15/2013	2	1	B	7.12	na
11/15/2013	2	1	C	7.08	7.20
11/15/2013	2	2	A	7.12	7.48
11/15/2013	2	2	B	7.12	7.46
11/15/2013	2	2	C	7.08	7.58
11/15/2013	2	3	A	7.12	7.61
11/15/2013	2	3	B	7.12	7.55
11/15/2013	2	3	C	7.08	7.56
11/19/2013	24	1	A	6.90	7.21
11/19/2013	24	1	B	6.90	6.86
11/19/2013	24	1	C	6.96	7.03
11/19/2013	24	2	A	6.90	7.12
11/19/2013	24	2	B	6.90	6.95
11/19/2013	24	2	C	6.96	7.23
11/19/2013	24	3	A	6.90	7.42
11/19/2013	24	3	B	6.90	7.37
11/19/2013	24	3	C	6.96	7.52
11/22/2013	2	1	A	7.38	7.33
11/22/2013	2	1	B	7.38	7.23
11/22/2013	2	1	C	7.33	7.48
11/22/2013	2	2	A	7.38	7.51
11/22/2013	2	2	B	7.38	7.45

Columns Run Date	Flow Duration (hours)	Column BAM #	Column Type	UCF Analyzed: Influent pH	UCF Analyzed: Effluent pH
11/22/2013	2	2	C	7.33	7.57
11/22/2013	2	3	A	7.38	7.66
11/22/2013	2	3	B	7.38	7.68
11/22/2013	2	3	C	7.33	7.77
12/3/2013	24	1	A	7.02	6.98
12/3/2013	24	1	B	7.02	6.78
12/3/2013	24	1	C	7.10	6.88
12/3/2013	24	2	A	7.02	6.92
12/3/2013	24	2	B	7.02	6.82
12/3/2013	24	2	C	7.10	7.14
12/3/2013	24	3	A	7.02	7.31
12/3/2013	24	3	B	7.02	7.21
12/3/2013	24	3	C	7.10	7.34
12/6/2013	2	1	A	7.16	7.29
12/6/2013	2	1	B	7.16	7.17
12/6/2013	2	1	C	7.20	7.43
12/6/2013	2	2	A	7.16	7.34
12/6/2013	2	2	B	7.16	7.44
12/6/2013	2	2	C	7.20	7.57
12/6/2013	2	3	A	7.16	7.57
12/6/2013	2	3	B	7.16	7.57
12/6/2013	2	3	C	7.20	7.55
12/11/2013	2	1	A	7.31	7.52
12/11/2013	2	1	B	7.31	7.19
12/11/2013	2	1	C	7.75	7.51
12/11/2013	2	2	A	7.31	7.52
12/11/2013	2	2	B	7.31	7.58
12/11/2013	2	2	C	7.75	7.56
12/11/2013	2	3	A	7.31	7.69
12/11/2013	2	3	B	7.31	7.75
12/11/2013	2	3	C	7.75	7.42
12/12/2013	24	1	A	7.34	7.18
12/12/2013	24	1	B	7.34	6.95
12/12/2013	24	1	C	7.44	7.08
12/12/2013	24	2	A	7.34	7.22
12/12/2013	24	2	B	7.34	7.14
12/12/2013	24	2	C	7.44	7.39
12/12/2013	24	3	A	7.34	7.45
12/12/2013	24	3	B	7.34	7.55

Columns Run Date	Flow Duration (hours)	Column BAM #	Column Type	UCF Analyzed: Influent pH	UCF Analyzed: Effluent pH
12/12/2013	24	3	C	7.44	7.57

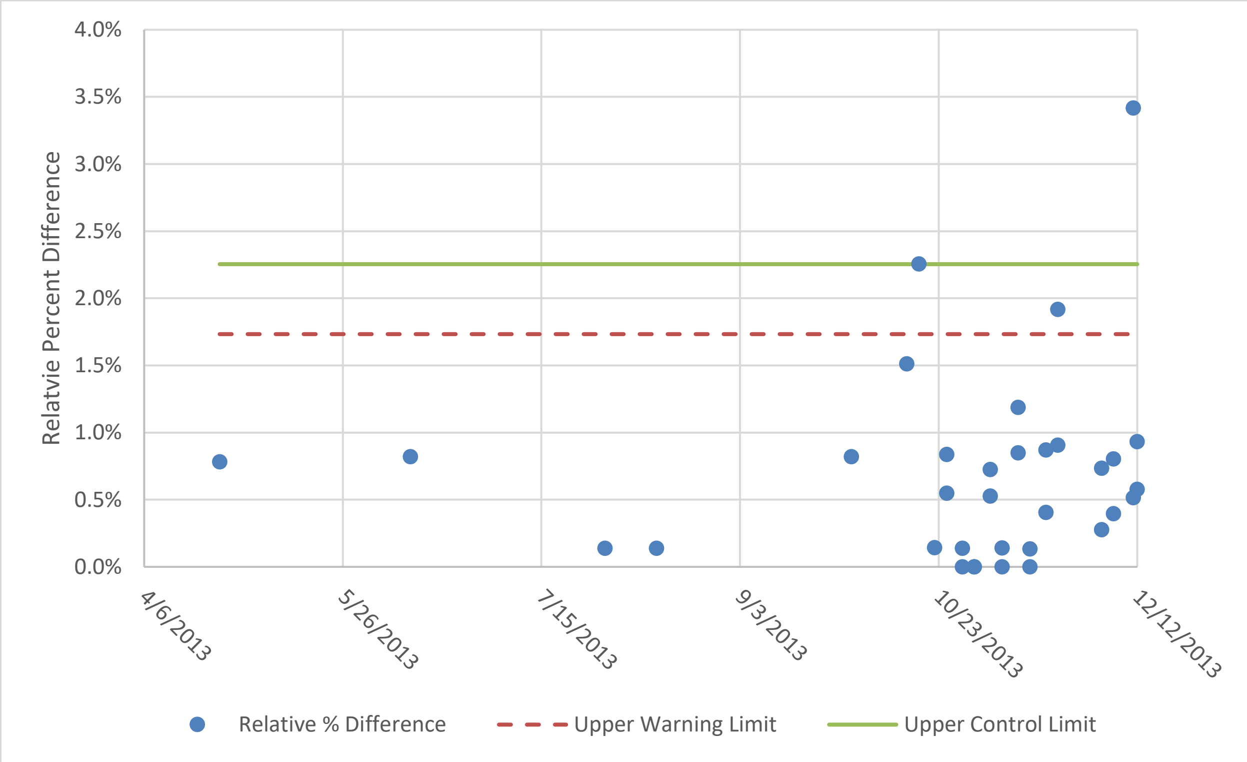


Figure 40: pH Precision Control Chart

APPENDIX F
TURBIDITY DATA

Table 58: Turbidity Data

Columns Run Date	Approximate Flow Duration (hours)	Column Media #	Column Type	Influent Turbidity (NTU)	Effluent Turbidity (NTU)
4/25/2013	2	1	A	5.92	7.72
4/25/2013	2	1	B	5.92	3.77
4/25/2013	2	2	A	5.92	15.60
4/25/2013	2	2	B	5.92	25.90
4/25/2013	2	3	A	5.92	5.77
4/25/2013	2	3	B	5.92	5.86
4/30/2013	2	1	A	1.74	1.61
4/30/2013	2	1	B	1.74	2.54
4/30/2013	2	2	A	1.74	5.39
4/30/2013	2	2	B	1.74	14.50
4/30/2013	2	3	A	1.74	15.06
4/30/2013	2	3	B	1.74	5.44
5/1/2013	2	1	A	3.82	1.98
5/1/2013	2	1	B	3.82	2.82
5/1/2013	2	2	A	3.82	6.56
5/1/2013	2	2	B	3.82	17.80
5/1/2013	2	3	A	3.82	4.30
5/1/2013	2	3	B	3.82	1.03
5/7/2013	2	1	A	3.68	3.54
5/7/2013	2	1	B	3.68	4.70
5/7/2013	2	2	A	3.68	11.40
5/7/2013	2	2	B	3.68	17.80
5/7/2013	2	3	A	3.68	5.29
5/7/2013	2	3	B	3.68	3.73
6/6/2013	2	1	A	4.20	4.69
6/6/2013	2	1	B	4.20	6.34
6/6/2013	2	2	A	4.20	7.42
6/6/2013	2	2	B	4.20	14.40
6/6/2013	2	3	A	4.20	6.96
6/6/2013	2	3	B	4.20	3.07
6/12/2013	2	1	A	7.62	7.08
6/12/2013	2	1	B	7.62	10.20
6/12/2013	2	2	A	7.62	5.23
6/12/2013	2	2	B	7.62	24.50
6/12/2013	2	3	A	7.62	4.35
6/12/2013	2	3	B	7.62	2.68
6/13/2013	2	1	A	17.90	6.41

Columns Run Date	Approximate Flow Duration (hours)	Column Media #	Column Type	Influent Turbidity (NTU)	Effluent Turbidity (NTU)
6/13/2013	2	1	B	17.90	7.61
6/13/2013	2	2	A	17.90	2.96
6/13/2013	2	2	B	17.90	22.60
6/13/2013	2	3	A	17.90	3.36
6/13/2013	2	3	B	17.90	3.21
6/20/2013	2	1	A	2.99	5.50
6/20/2013	2	1	B	2.99	4.38
6/20/2013	2	2	A	2.99	4.60
6/20/2013	2	2	B	2.99	42.80
6/20/2013	2	3	A	2.99	5.05
6/20/2013	2	3	B	2.99	9.85
6/24/2013	2	1	A	2.20	2.80
6/24/2013	2	1	B	2.20	3.40
6/24/2013	2	2	A	2.20	2.50
6/24/2013	2	2	B	2.20	14.90
6/24/2013	2	3	A	2.20	2.40
6/24/2013	2	3	B	2.20	2.70
6/25/2013	24	1	A	1.15	2.41
6/25/2013	24	1	B	1.15	2.73
6/25/2013	24	2	A	1.15	0.92
6/25/2013	24	2	B	1.15	2.34
6/25/2013	24	3	A	1.15	1.73
6/25/2013	24	3	B	1.15	1.92
7/2/2013	2	1	A	13.00	7.00
7/2/2013	2	1	B	13.00	8.00
7/2/2013	2	2	A	13.00	6.00
7/2/2013	2	2	B	13.00	14.00
7/2/2013	2	3	A	13.00	4.00
7/2/2013	2	3	B	13.00	12.00
7/11/2013	24	1	A	6.40	3.01
7/11/2013	24	1	B	6.40	3.05
7/11/2013	24	2	A	6.40	1.37
7/11/2013	24	2	B	6.40	3.15
7/11/2013	24	3	A	6.40	3.24
7/11/2013	24	3	B	6.40	1.11
7/24/2013	24	1	A	6.41	5.90
7/24/2013	24	1	B	6.41	4.97
7/24/2013	24	2	A	6.41	3.23
7/24/2013	24	2	B	6.41	6.04
7/24/2013	24	3	A	6.41	5.27

Columns Run Date	Approximate Flow Duration (hours)	Column Media #	Column Type	Influent Turbidity (NTU)	Effluent Turbidity (NTU)
7/24/2013	24	3	B	6.41	2.04
7/26/2013	2	1	A	1.28	1.53
7/26/2013	2	1	B	1.28	1.70
7/26/2013	2	2	A	1.28	1.65
7/26/2013	2	2	B	1.28	1.66
7/26/2013	2	3	A	1.28	3.14
7/26/2013	2	3	B	1.28	1.42
7/31/2013	2	1	A	1.18	1.12
7/31/2013	2	1	B	1.18	1.28
7/31/2013	2	2	A	1.18	1.11
7/31/2013	2	2	B	1.18	3.65
7/31/2013	2	3	A	1.18	0.90
7/31/2013	2	3	B	1.18	1.40
8/1/2013	24	1	A	0.86	1.17
8/1/2013	24	1	B	0.86	0.74
8/1/2013	24	2	A	0.86	0.98
8/1/2013	24	2	B	0.86	0.71
8/1/2013	24	3	A	0.86	0.86
8/1/2013	24	3	B	0.86	0.78
8/5/2013	24	1	A	3.37	2.16
8/5/2013	24	1	B	3.37	1.26
8/5/2013	24	2	A	3.34	1.43
8/5/2013	24	2	B	3.37	1.07
8/5/2013	24	3	A	3.37	1.61
8/5/2013	24	3	B	3.37	1.57
8/7/2013	2	1	A	2.92	1.63
8/7/2013	2	1	B	2.92	2.54
8/7/2013	2	2	A	2.92	2.54
8/7/2013	2	2	B	2.92	7.87
8/7/2013	2	3	A	2.92	27.70
8/7/2013	2	3	B	2.92	1.31
8/13/2013	24	1	A	0.68	1.21
8/13/2013	24	1	B	0.68	0.98
8/13/2013	24	2	A	0.68	0.81
8/13/2013	24	2	B	0.68	0.96
8/13/2013	24	3	A	0.68	2.33
8/13/2013	24	3	B	0.68	1.03
8/15/2013	2	1	A	1.47	1.64
8/15/2013	2	1	B	1.47	6.78
8/15/2013	2	2	A	1.47	1.59

Columns Run Date	Approximate Flow Duration (hours)	Column Media #	Column Type	Influent Turbidity (NTU)	Effluent Turbidity (NTU)
8/15/2013	2	2	B	1.47	2.80
8/15/2013	2	3	A	1.47	1.37
8/15/2013	2	3	B	1.47	1.12
8/27/2013	24	1	A	1.67	2.57
8/27/2013	24	1	B	1.67	1.98
8/27/2013	24	2	A	1.67	1.17
8/27/2013	24	2	B	1.67	1.44
8/27/2013	24	3	A	1.67	1.13
8/27/2013	24	3	B	1.67	1.03
9/3/2013	24	1	A	2.29	1.97
9/3/2013	24	1	B	2.29	1.49
9/3/2013	24	2	A	2.29	1.27
9/3/2013	24	2	B	2.29	1.30
9/3/2013	24	3	A	2.29	1.22
9/3/2013	24	3	B	2.29	1.00
9/24/2013	24	1	A	5.54	6.77
9/24/2013	24	1	B	5.54	4.91
9/24/2013	24	2	A	5.54	1.92
9/24/2013	24	2	B	5.54	4.74
9/24/2013	24	3	A	5.54	5.68
9/24/2013	24	3	B	5.54	2.69
9/27/2013	2	1	A	6.53	1.82
9/27/2013	2	1	B	6.53	1.79
9/27/2013	2	2	A	6.53	1.95
9/27/2013	2	2	B	6.53	2.63
9/27/2013	2	3	A	6.53	1.17
9/27/2013	2	3	B	6.53	0.93
10/1/2013	24	1	A	4.19	1.97
10/1/2013	24	1	B	4.19	1.98
10/1/2013	24	2	A	4.19	1.41
10/1/2013	24	2	B	4.19	1.29
10/1/2013	24	3	A	4.19	1.57
10/1/2013	24	3	B	4.19	1.92
10/4/2013	2	1	A	5.90	1.65
10/4/2013	2	1	B	5.90	1.64
10/4/2013	2	2	A	5.90	6.70
10/4/2013	2	2	B	5.90	30.70
10/4/2013	2	3	A	5.90	1.43
10/4/2013	2	3	B	5.90	2.18
10/8/2013	24	1	A	2.17	2.26

Columns Run Date	Approximate Flow Duration (hours)	Column Media #	Column Type	Influent Turbidity (NTU)	Effluent Turbidity (NTU)
10/8/2013	24	1	B	2.17	2.87
10/8/2013	24	2	A	2.17	2.20
10/8/2013	24	2	B	2.17	1.98
10/8/2013	24	3	A	2.17	1.82
10/8/2013	24	3	B	2.17	2.38
10/15/2013	24	1	A	3.50	1.60
10/15/2013	24	1	B	3.50	1.48
10/15/2013	24	2	A	3.50	1.39
10/15/2013	24	2	B	3.50	2.67
10/15/2013	24	3	A	3.50	1.62
10/15/2013	24	3	B	3.50	1.97
10/18/2013	2	1	A	na	2.42
10/18/2013	2	1	B	na	1.40
10/18/2013	2	2	A	na	1.81
10/18/2013	2	2	B	na	6.25
10/18/2013	2	3	A	na	1.48
10/18/2013	2	3	B	na	1.28
10/22/2013	24	1	A	1.54	2.56
10/22/2013	24	1	B	1.54	1.92
10/22/2013	24	2	A	1.54	1.17
10/22/2013	24	2	B	1.54	1.79
10/22/2013	24	3	A	1.54	1.65
10/22/2013	24	3	B	1.54	1.46
10/25/2013	2	1	A	2.18	1.89
10/25/2013	2	1	B	2.18	1.77
10/25/2013	2	2	A	2.18	1.61
10/25/2013	2	2	B	2.18	2.19
10/25/2013	2	3	A	2.18	1.66
10/25/2013	2	3	B	2.18	1.74
10/29/2013	24	1	A	1.66	1.54
10/29/2013	24	1	B	1.66	1.35
10/29/2013	24	2	A	1.66	1.18
10/29/2013	24	2	B	1.66	2.24
10/29/2013	24	3	A	1.66	1.06
10/29/2013	24	3	B	1.66	1.05
11/1/2013	2	1	A	3.25	1.45
11/1/2013	2	1	B	3.25	1.21
11/1/2013	2	2	A	3.25	1.56
11/1/2013	2	2	B	3.25	4.26
11/1/2013	2	3	A	3.25	1.18

Columns Run Date	Approximate Flow Duration (hours)	Column Media #	Column Type	Influent Turbidity (NTU)	Effluent Turbidity (NTU)
11/1/2013	2	3	B	3.25	1.36
11/5/2013	24	1	A	1.82	1.29
11/5/2013	24	1	B	1.82	1.76
11/5/2013	24	2	A	1.82	1.16
11/5/2013	24	2	B	1.82	1.31
11/5/2013	24	3	A	1.82	1.30
11/5/2013	24	3	B	1.82	1.12
11/8/2013	2	1	A	1.97	1.00
11/8/2013	2	1	B	1.97	0.91
11/8/2013	2	2	A	1.97	0.88
11/8/2013	2	2	B	1.97	3.75
11/8/2013	2	3	A	1.97	0.95
11/8/2013	2	3	B	1.97	0.78
11/12/2013	24	1	A	1.82	2.10
11/12/2013	24	1	B	1.82	1.64
11/12/2013	24	2	A	1.82	1.44
11/12/2013	24	2	B	1.82	2.09
11/12/2013	24	3	A	1.82	1.49
11/12/2013	24	3	B	1.82	1.45
11/15/2013	2	1	A	1.75	1.22
11/15/2013	2	1	B	1.75	na
11/15/2013	2	2	A	1.75	1.09
11/15/2013	2	2	B	1.75	3.64
11/15/2013	2	3	A	1.75	1.04
11/15/2013	2	3	B	1.75	1.72
11/19/2013	24	1	A	1.25	1.13
11/19/2013	24	2	A	1.25	3.27
11/19/2013	24	3	A	1.25	0.83
11/22/2013	2	1	A	4.90	1.64
11/22/2013	2	2	A	4.90	58.70
11/22/2013	2	3	A	4.90	1.49
12/3/2013	24	1	A	1.23	1.03
12/3/2013	24	2	A	1.23	3.30
12/3/2013	24	3	A	1.23	1.35
12/6/2013	2	1	A	3.34	1.07
12/6/2013	2	2	A	3.34	8.22
12/6/2013	2	3	A	3.34	1.65
12/11/2013	2	1	A	1.22	0.96
12/11/2013	2	2	A	1.22	24.40
12/11/2013	2	3	A	1.22	2.05

Columns Run Date	Approximate Flow Duration (hours)	Column Media #	Column Type	Influent Turbidity (NTU)	Effluent Turbidity (NTU)
12/12/2013	24	1	A	1.89	1.33
12/12/2013	24	2	A	1.89	11.00
12/12/2013	24	3	A	1.89	1.43

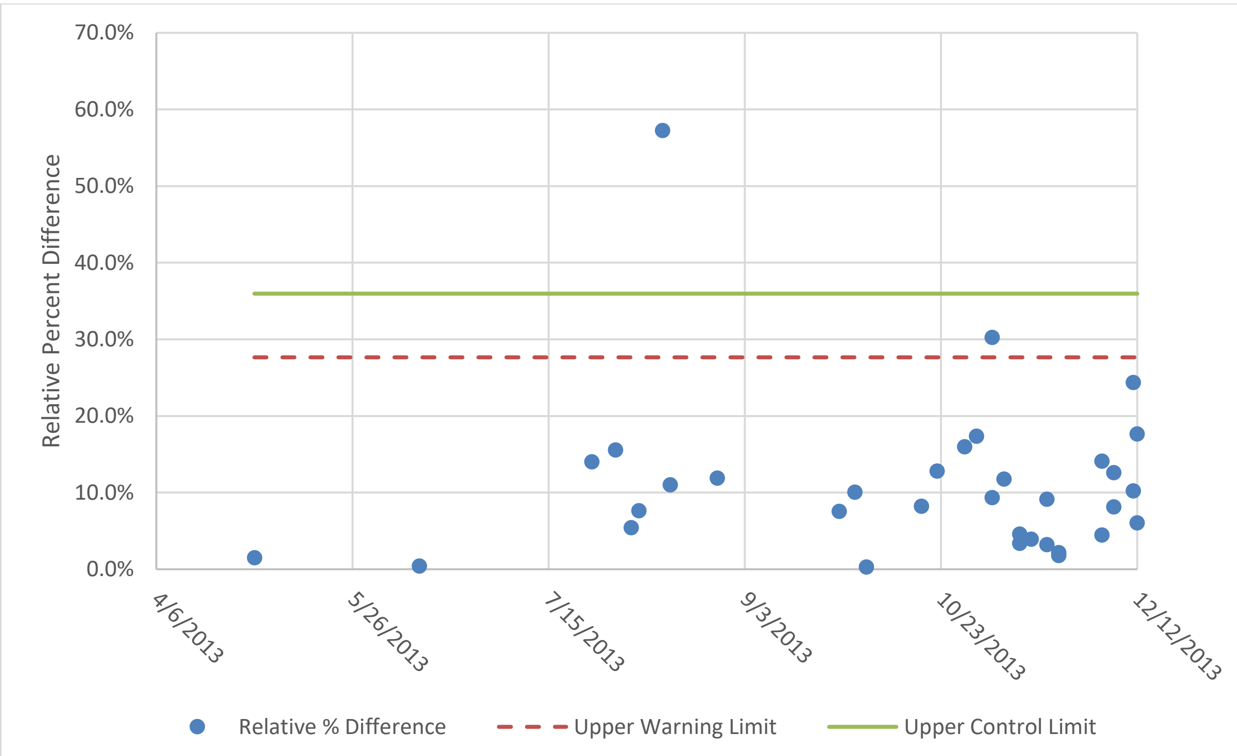


Figure 41: Turbidity Precision Control Chart

APPENDIX G
TSS DATA

Table 59: TSS Data from Environmental Research & Design Commercial Lab

Columns Run Date	Approximate Flow Duration (hours)	Column Media #	Column Type	ERD Analyzed: Influent TSS (mg/L)	ERD Analyzed: Effluent TSS (mg/L)
5/1/2013	2	1	A	1.8	1
5/1/2013	2	1	B	1.8	1.4
5/1/2013	2	1	C	1.8	1.2
5/1/2013	2	2	A	1.8	2.6
5/1/2013	2	2	B	1.8	7.4
5/1/2013	2	2	C	1.8	16.2
5/1/2013	2	3	A	1.8	0.6
5/1/2013	2	3	B	1.8	61.2
5/1/2013	2	3	C	1.8	1
6/6/2013	2	1	A	3.8	3.4
6/6/2013	2	1	B	3.8	3.8
6/6/2013	2	1	C	3.8	1.2
6/6/2013	2	2	A	3.8	2.4
6/6/2013	2	2	B	3.8	3.8
6/6/2013	2	2	C	3.8	81.4
6/6/2013	2	3	A	3.8	1.2
6/6/2013	2	3	B	3.8	1.8
6/6/2013	2	3	C	3.8	1.7
6/13/2013	2	1	A	4.2	1.4
6/13/2013	2	1	B	4.2	2.2
6/13/2013	2	1	C	4.2	2.4
6/13/2013	2	2	A	4.2	1
6/13/2013	2	2	B	4.2	6.2
6/13/2013	2	2	C	4.2	34.4
6/13/2013	2	3	A	4.2	1
6/13/2013	2	3	B	4.2	1
6/13/2013	2	3	C	4.2	3.2
6/20/2013	2	1	A	2.4	1.6
6/20/2013	2	1	B	2.4	1.8
6/20/2013	2	1	C	2.4	3.8
6/20/2013	2	2	A	2.4	1.2
6/20/2013	2	2	B	2.4	38.6
6/20/2013	2	2	C	2.4	60.4
6/20/2013	2	3	A	2.4	3.4
6/20/2013	2	3	B	2.4	1
6/20/2013	2	3	C	2.4	2.2

Columns Run Date	Approximate Flow Duration (hours)	Column Media #	Column Type	ERD Analyzed: Influent TSS (mg/L)	ERD Analyzed: Effluent TSS (mg/L)
6/25/2013	24	1	A	1.6	1
6/25/2013	24	1	B	1.6	4.2
6/25/2013	24	1	C	1.6	2.2
6/25/2013	24	2	A	1.6	0.8
6/25/2013	24	2	B	1.6	0.6
6/25/2013	24	2	C	1.6	1.2
6/25/2013	24	3	A	1.6	0.6
6/25/2013	24	3	B	1.6	2
6/25/2013	24	3	C	1.6	1.2
7/2/2013	2	1	A	10.4	3
7/2/2013	2	1	B	10.4	6.2
7/2/2013	2	1	C	10.4	6.4
7/2/2013	2	2	A	10.4	1.8
7/2/2013	2	2	B	10.4	1.6
7/2/2013	2	2	C	10.4	8.8
7/2/2013	2	3	A	10.4	2
7/2/2013	2	3	B	10.4	3.2
7/2/2013	2	3	C	10.4	4.8

Table 60: TSS Data from UCF Stormwater Lab

Columns Run Date	Approximate Flow Duration (hours)	Column Media #	Column Type	UCF Analyzed: Influent TSS (mg/L)	UCF Analyzed: Effluent TSS (mg/L)
7/2/2013	2	1	A	21.33	8.50
7/2/2013	2	1	B	21.33	24.00
7/2/2013	2	1	C	14.00	24.00
7/2/2013	2	2	A	21.33	50.00
7/2/2013	2	2	B	21.33	23.33
7/2/2013	2	2	C	14.00	26.50
7/2/2013	2	3	A	21.33	0.00
7/2/2013	2	3	B	21.33	27.50
7/2/2013	2	3	C	14.00	3.50
7/11/2013	24	1	A	6.80	-19.00
7/11/2013	24	1	B	6.80	-6.00
7/11/2013	24	1	C	12.80	-7.33
7/11/2013	24	2	A	6.80	4.80
7/11/2013	24	2	B	6.80	-16.80
7/11/2013	24	2	C	12.80	2.40
7/11/2013	24	3	A	6.80	4.40
7/11/2013	24	3	B	6.80	-7.60
7/11/2013	24	3	C	12.80	10.40
7/24/2013	24	1	A	2.00	2.50
7/24/2013	24	1	B	2.00	3.25
7/24/2013	24	1	C	2.12	4.50
7/24/2013	24	2	A	2.00	2.75
7/24/2013	24	2	B	2.00	1.00
7/24/2013	24	2	C	2.12	"10"
7/24/2013	24	3	A	2.00	23.00
7/24/2013	24	3	B	2.00	19.00
7/24/2013	24	3	C	2.12	21.00
7/26/2013	2	1	A	11.00	7.33
7/26/2013	2	1	B	11.00	10.67
7/26/2013	2	1	C	13.00	18.37
7/26/2013	2	2	A	11.00	8.00
7/26/2013	2	2	B	11.00	12.00
7/26/2013	2	2	C	13.00	15.00
7/26/2013	2	3	A	11.00	20.00
7/26/2013	2	3	B	11.00	4.50
7/26/2013	2	3	C	13.00	2.50
8/5/2013	24	1	A	3.00	2.25

Columns Run Date	Approximate Flow Duration (hours)	Column Media #	Column Type	UCF Analyzed: Influent TSS (mg/L)	UCF Analyzed: Effluent TSS (mg/L)
8/5/2013	24	1	B	3.00	2.25
8/5/2013	24	1	C	2.50	4.25
8/5/2013	24	2	A	3.00	3.50
8/5/2013	24	2	B	3.00	-0.25
8/5/2013	24	2	C	2.50	1.75
8/5/2013	24	3	A	3.00	1.75
8/5/2013	24	3	C	2.50	2.00
8/13/2013	24	1	A	2.00	2.75
8/13/2013	24	1	B	2.00	1.00
8/13/2013	24	1	C	1.75	2.00
8/13/2013	24	2	A	2.00	1.50
8/13/2013	24	2	B	2.00	2.25
8/13/2013	24	2	C	1.75	1.00
8/13/2013	24	3	A	2.00	4.00
8/13/2013	24	3	B	2.00	2.00
8/13/2013	24	3	C	1.75	1.75
8/15/2013	2	1	A	1.00	1.75
8/15/2013	2	1	B	1.00	1.25
8/15/2013	2	1	C	1.00	2.00
8/15/2013	2	2	A	1.00	1.00
8/15/2013	2	2	B	1.00	"4.00”
8/15/2013	2	2	C	1.00	0.25
8/15/2013	2	3	A	1.00	1.00
8/15/2013	2	3	B	1.00	0.25
8/15/2013	2	3	C	1.00	0.50
8/30/2013	2	1	A	8.25	2.50
8/30/2013	2	1	B	8.25	2.25
8/30/2013	2	1	C	10.00	3.50
8/30/2013	2	2	A	8.25	2.50
8/30/2013	2	2	B	8.25	5.75
8/30/2013	2	2	C	10.00	4.75
8/30/2013	2	3	A	8.25	1.25
8/30/2013	2	3	C	10.00	1.75
9/3/2013	24	1	A	1.25	2.50
9/3/2013	24	1	B	1.25	2.25
9/3/2013	24	1	C	1.25	2.50
9/3/2013	24	2	A	1.25	2.00
9/3/2013	24	2	B	1.25	2.00
9/3/2013	24	2	C	1.25	1.75

Columns Run Date	Approximate Flow Duration (hours)	Column Media #	Column Type	UCF Analyzed: Influent TSS (mg/L)	UCF Analyzed: Effluent TSS (mg/L)
9/3/2013	24	3	A	1.25	0.50
9/3/2013	24	3	B	1.25	1.75
9/3/2013	24	3	C	1.25	1.00
9/24/2013	24	1	A	3.50	5.25
9/24/2013	24	1	B	3.50	5.75
9/24/2013	24	1	C	1.00	2.75
9/24/2013	24	2	A	3.50	1.50
9/24/2013	24	2	B	3.50	5.25
9/24/2013	24	2	C	1.00	1.50
9/24/2013	24	3	A	3.50	3.25
9/24/2013	24	3	B	3.50	2.00
9/24/2013	24	3	C	1.00	1.50
9/27/2013	2	1	A	6.00	2.50
9/27/2013	2	1	B	6.00	1.25
9/27/2013	2	1	C	6.00	2.50
9/27/2013	2	2	A	6.00	1.50
9/27/2013	2	2	B	6.00	2.00
9/27/2013	2	2	C	6.00	2.50
9/27/2013	2	3	A	6.00	1.00
9/27/2013	2	3	B	6.00	0.25
9/27/2013	2	3	C	6.00	1.75
10/1/2013	24	1	A	4.00	2.50
10/1/2013	24	1	B	4.00	2.50
10/1/2013	24	1	C	5.00	3.00
10/1/2013	24	2	A	4.00	1.25
10/1/2013	24	2	B	4.00	1.00
10/1/2013	24	2	C	5.00	1.25
10/1/2013	24	3	A	4.00	0.25
10/1/2013	24	3	B	4.00	3.00
10/1/2013	24	3	C	5.00	2.25
10/4/2013	2	1	A	4.75	1.75
10/4/2013	2	1	B	4.75	0.50
10/4/2013	2	1	C	3.50	1.50
10/4/2013	2	2	A	4.75	3.75
10/4/2013	2	2	B	4.75	"20.25”
10/4/2013	2	2	C	3.50	"26.50”
10/4/2013	2	3	A	4.75	-0.75
10/4/2013	2	3	B	4.75	0.75
10/4/2013	2	3	C	3.50	0.75

Columns Run Date	Approximate Flow Duration (hours)	Column Media #	Column Type	UCF Analyzed: Influent TSS (mg/L)	UCF Analyzed: Effluent TSS (mg/L)
10/8/2013	24	1	A	4.75	1.75
10/8/2013	24	1	B	4.75	0.75
10/8/2013	24	1	C	2.75	2.00
10/8/2013	24	2	A	4.75	0.00
10/8/2013	24	2	B	4.75	0.25
10/8/2013	24	2	C	2.75	0.75
10/8/2013	24	3	A	4.75	1.00
10/8/2013	24	3	B	4.75	0.50
10/8/2013	24	3	C	2.75	-0.25
10/15/2013	24	1	A	4.25	2.50
10/15/2013	24	1	B	4.25	2.00
10/15/2013	24	1	C	2.50	2.50
10/15/2013	24	2	A	4.25	1.25
10/15/2013	24	2	B	4.25	4.25
10/15/2013	24	2	C	2.50	1.75
10/15/2013	24	3	A	4.25	2.00
10/15/2013	24	3	B	4.25	1.75
10/15/2013	24	3	C	2.50	2.00
10/18/2013	2	1	A	3.75	2.00
10/18/2013	2	1	B	3.75	1.25
10/18/2013	2	1	C	3.25	1.00
10/18/2013	2	2	A	3.75	1.75
10/18/2013	2	2	B	3.75	1.75
10/18/2013	2	2	C	3.25	3.00
10/18/2013	2	3	A	3.75	1.75
10/18/2013	2	3	B	3.75	1.00
10/18/2013	2	3	C	3.25	1.50
10/22/2013	24	1	A	1.50	3.25
10/22/2013	24	1	B	1.50	2.25
10/22/2013	24	1	C	1.00	1.25
10/22/2013	24	2	A	1.50	1.75
10/22/2013	24	2	B	1.50	2.00
10/22/2013	24	2	C	1.00	1.00
10/22/2013	24	3	A	1.50	1.75
10/22/2013	24	3	B	1.50	1.75
10/22/2013	24	3	C	1.00	1.25
10/25/2013	2	1	A	7.00	1.75
10/25/2013	2	1	B	7.00	2.00
10/25/2013	2	1	C	4.50	1.50

Columns Run Date	Approximate Flow Duration (hours)	Column Media #	Column Type	UCF Analyzed: Influent TSS (mg/L)	UCF Analyzed: Effluent TSS (mg/L)
10/25/2013	2	2	A	7.00	2.50
10/25/2013	2	2	B	7.00	2.50
10/25/2013	2	2	C	4.50	5.25
10/25/2013	2	3	A	7.00	1.75
10/25/2013	2	3	B	7.00	1.00
10/25/2013	2	3	C	4.50	0.75
10/29/2013	24	1	A	3.00	2.50
10/29/2013	24	1	B	3.00	2.50
10/29/2013	24	1	C	1.50	2.25
10/29/2013	24	2	A	3.00	2.50
10/29/2013	24	2	B	3.00	2.50
10/29/2013	24	2	C	1.50	2.25
10/29/2013	24	3	A	3.00	2.50
10/29/2013	24	3	B	3.00	2.50
10/29/2013	24	3	C	1.50	2.25
11/1/2013	2	1	A	2.50	1.75
11/1/2013	2	1	B	2.50	1.25
11/1/2013	2	1	C	2.25	1.50
11/1/2013	2	2	A	2.50	2.25
11/1/2013	2	2	B	2.50	"5"
11/1/2013	2	2	C	2.25	"8.00"
11/1/2013	2	3	A	2.50	2.00
11/1/2013	2	3	B	2.50	2.00
11/1/2013	2	3	C	2.25	2.25
11/5/2013	24	1	A	1.00	2.00
11/5/2013	24	1	B	1.00	2.50
11/5/2013	24	1	C	1.00	1.25
11/5/2013	24	2	A	1.00	0.75
11/5/2013	24	2	B	1.00	1.25
11/5/2013	24	2	C	1.00	1.50
11/5/2013	24	3	A	1.00	1.25
11/5/2013	24	3	B	1.00	1.00
11/5/2013	24	3	C	1.00	0.75
11/8/2013	2	1	A	2.25	2.00
11/8/2013	2	1	B	2.25	0.75
11/8/2013	2	1	C	3.75	1.00
11/8/2013	2	2	A	2.25	1.00
11/8/2013	2	2	B	2.25	2.50
11/8/2013	2	2	C	3.75	3.50

Columns Run Date	Approximate Flow Duration (hours)	Column Media #	Column Type	UCF Analyzed: Influent TSS (mg/L)	UCF Analyzed: Effluent TSS (mg/L)
11/8/2013	2	3	A	2.25	2.00
11/8/2013	2	3	B	2.25	0.00
11/8/2013	2	3	C	3.75	0.50
11/12/2013	24	1	A	0.75	1.00
11/12/2013	24	1	B	0.75	0.75
11/12/2013	24	1	C	4.00	0.00
11/12/2013	24	2	A	0.75	0.50
11/12/2013	24	2	B	0.75	0.50
11/12/2013	24	2	C	4.00	1.25
11/12/2013	24	3	A	0.75	0.25
11/12/2013	24	3	B	0.75	0.25
11/12/2013	24	3	C	4.00	0.75
11/15/2013	2	1	A	2.50	1.48
11/15/2013	2	1	C	5.25	1.75
11/15/2013	2	2	A	2.50	1.00
11/15/2013	2	2	B	2.50	2.00
11/15/2013	2	2	C	5.25	"14.50"
11/15/2013	2	3	A	2.50	0.50
11/15/2013	2	3	B	2.50	0.50
11/15/2013	2	3	C	5.25	0.25
11/19/2013	24	1	A	1.25	1.25
11/19/2013	24	1	B	1.25	0.75
11/19/2013	24	1	C	0.75	0.75
11/19/2013	24	2	A	1.25	1.50
11/19/2013	24	2	B	1.25	8.00
11/19/2013	24	2	C	0.75	2.25
11/19/2013	24	3	A	1.25	1.00
11/19/2013	24	3	B	1.25	25.00
11/19/2013	24	3	C	0.75	0.75
11/22/2013	2	1	A	7.25	0.50
11/22/2013	2	1	B	7.25	1.00
11/22/2013	2	1	C	12.25	1.75
11/22/2013	2	2	A	7.25	44.75
11/22/2013	2	2	B	7.25	19.00
11/22/2013	2	2	C	12.25	12.75
11/22/2013	2	3	A	7.25	1.50
11/22/2013	2	3	B	7.25	1.75
11/22/2013	2	3	C	12.25	1.00
12/3/2013	24	1	B	na	2.25

Columns Run Date	Approximate Flow Duration (hours)	Column Media #	Column Type	UCF Analyzed: Influent TSS (mg/L)	UCF Analyzed: Effluent TSS (mg/L)
12/3/2013	24	2	B	na	7.25
12/3/2013	24	3	B	na	2.00
12/11/2013	2	1	A	1.75	1.25
12/11/2013	2	1	B	1.75	0.50
12/11/2013	2	1	C	1.75	0.25
12/11/2013	2	2	A	1.75	22.25
12/11/2013	2	2	B	1.75	15.25
12/11/2013	2	2	C	1.75	62.75
12/11/2013	2	3	A	1.75	1.00
12/11/2013	2	3	B	1.75	3.25
12/11/2013	2	3	C	1.75	9.00
12/12/2013	24	1	A	4.25	1.25
12/12/2013	24	1	B	4.25	1.00
12/12/2013	24	1	C	1.50	0.50
12/12/2013	24	2	A	4.25	5.50
12/12/2013	24	2	B	4.25	6.25
12/12/2013	24	2	C	1.50	7.25
12/12/2013	24	3	A	4.25	0.75
12/12/2013	24	3	B	4.25	"415"
12/12/2013	24	3	C	1.50	1.00

Only TSS data from the A & B Columns was used in the analysis.

APPENDIX H
ALTERNATIVE POWERMAX® SOIL DNA ISOLATION KIT PROTOCOL FOR SOILS WITH HIGH CLAY CONTENT

Re: [##21356##] low yields with high clay soil

mobio92010@zohosupport.com
on behalf of
MO BIO Technical Support <technical@mobio.com>
Mon 6/29/2015 5:35 PM

To: Drew Hood <andrewhood@knights.ucf.edu>
Cc: technical@mobio.com <technical@mobio.com>

Dear Andrew,

Thank you for calling MO BIO today regarding the PowerMax kit and extracting DNA from a high clay soil. Below, I have copied our alternative protocol for isolating DNA/RNA from a low biomass soil. It also works well for a high clay soil. Let me know if you have any questions.

Best regards,

Michelle

Michelle Tetreault Carlson, PhD | Technical Support Manager
MO BIO Laboratories, Inc. *Saving you time for life*
2746 Loker Avenue West, Carlsbad, CA 92010
E-mail: mtcarlson@mobio.com Office: +1.760-929-9911 x136

Alternative PowerMax Protocols for RNA and DNA from Low Biomass Soil with High Humics

1. Add 5 grams of soil to the bead tube.
2. Add 5 ml of phenol:chloroform:isoamyl alcohol pH 7-8 [For example Sigma Product P2069.]
3. Add 10 ml Bead Solution and 1 ml Solution C1 and 0.5 ml of Solution C2
4. Homogenize on the vortex 10 minutes.
5. Centrifuge 4500 x g for 8 minutes. If you can't spin that hard, spin longer (2500 x g for 15 minutes)
6. Remove the supernatant. Depending on the soil, you may have an upper aqueous layer or not. If you do, remove only the upper aqueous layer to the new tube. (~10 ml) If RNA is not desired add 10 ul of RNase A to the collection tube after the aqueous portion is transferred.
7. Add 3 ml of C3, mix, incubate 5 minutes 4C and then centrifuge for 5 minutes at 4500 x g.
8. Transfer the supernatant to a new tube (~13-14 ml).
9. Add equal volume (14 ml) of Solution C4. Add 14 ml of 100% ethanol. Mix well (vortex or invert).
10. Load 21 ml of lysate onto the max column (~ half of your lysate, I load up to 22 ml).
11. Centrifuge 3 minutes at 4500 x g. Discard the flow-through.
12. Repeat step 10 and 11 to load the rest of the lysate.
13. To prepare the first wash buffer, per prep, add 9 ml of Solution C4 in a 50 ml tube and 11 ml of 100% ethanol. Add to the column. Centrifuge 4500 x g for 3 minutes. Discard the flow-through.
14. Wash with 20 ml of Solution C5. Centrifuge 3 minutes at 4500 x g. Discard the flow-through.
15. Wash with 20 ml of 100% ethanol. Centrifuge 3 minutes at 4500 x g. Discard the flow-through.
16. Centrifuge to dry the column 10 minutes at 4500 x g.
17. Take the column and place it into a new 50 ml tube and leave the cap off and let it air dry for

10 minutes open. Sometimes we have ethanol carry-over if we do not do this.
18. Elute the DNA/RNA in 6 ml elution buffer.
19. Centrifuge 5 minutes at 4500 x g.
20. I take a 50 ul aliquot of this and check it on a nanodrop or a gel.

21. To concentrate the DNA, add NaCl to final concentration of 0.2M (so 240 ul of 5M NaCl (expect 5.5 ml out) and add linear acrylamide, try 20 ul of 5mg/ml [Amresco, Biotechnology grade]). Add 2.5 volumes of 100% ethanol (14 ml). Invert or shake or vortex to mix well and then freeze -20C for at least an hour or overnight.
22. Next day, centrifuge 35 minutes at 4500 x g to pellet the DNA/RNA. Wash the pellet with 70% ethanol (5 ml) and then centrifuge again 10 minutes at 4500 x g to re-pellet. Decant the ethanol, invert the tube to drain, then turn right side up and let air dry until traces of ethanol are mostly gone. Resuspend the pellet in a suitable volume - maybe 50-100 ul for a low biomass soil but check the pellet and see. You will get a much higher yield so the pellet could be larger than you are used to seeing. You may need to resuspend it in 200 ul.

APPENDIX I
PARTICLE SIZE DISTRIBUTIONS & PHOTOS of BAM

The American Association of State Highway and Transportation Officials (AASHTO) soil classification system is based on the particle size distribution and plasticity [49, 138]. There are seven groups of soil based on particle size, sub classification is based on plasticity [138]. For the purposes of this research, particle size distribution was the parameter of interest.

The experimental design analyzed three types of BAM mixes, the various components of which were: 50/50 volumetric ratio blend of course and fine expanded clay (hence forth referred to as 50/50 expanded clay), ⅜-inch expanded clay, automobile tire crumb (1–5 mm), limestone screenings, AASHTO A-3 sand with 1.8% silt/clay, and AASHTO A-3 sand with 7.1% silt/clay. AASHTO A-3 sand is defined as having a minimum of 51% passing the #40 sieve (0.425 mm) and a maximum of 10% passing the #200 sieve (0.075 mm) [50, 138].

The BAM mixtures, 3/8 inch expanded clay, 50/50 expanded clay, tire crumb, and lime stone screenings are manufactured products, not natural soils, and thus do not receive an AASHTO classification.

Particle size distribution was determined using a sieve test [49, 50]. Particle size distribution curves for the various components used to make the BAM are presented in Figure 42, Figure 43, Figure 44. Figure 45, and Figure 46. Particle size distribution curves for the three BAM types analyzed are presented in Figure 47, Figure 48, and Figure 49. Photographs of the BAM types analyzed are presented in Figure 50, Figure 51, and Figure 52.

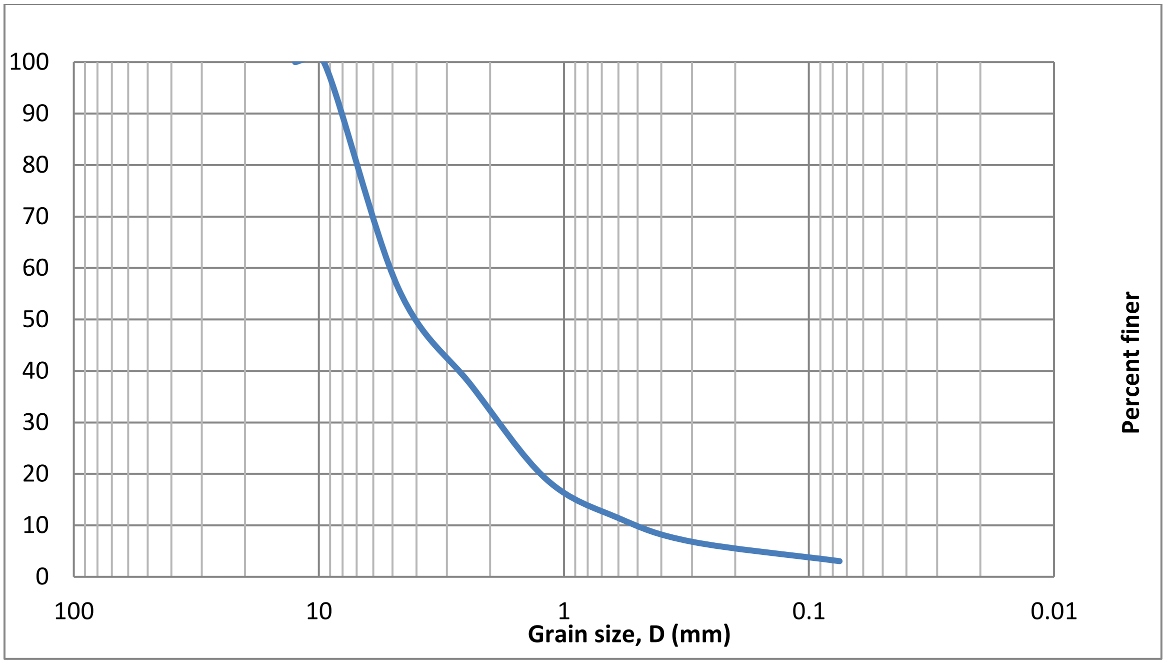


Figure 42: Particle Size Distribution for 3/8 inch Expanded Clay

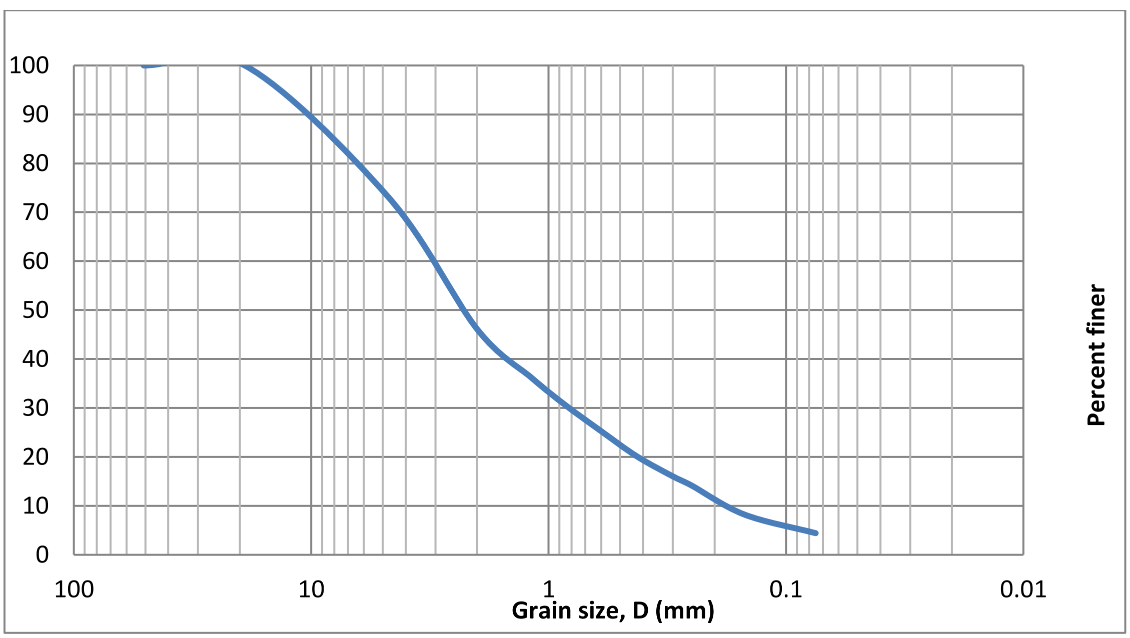


Figure 43: Particle Size Distribution for 50/50 Expanded Clay

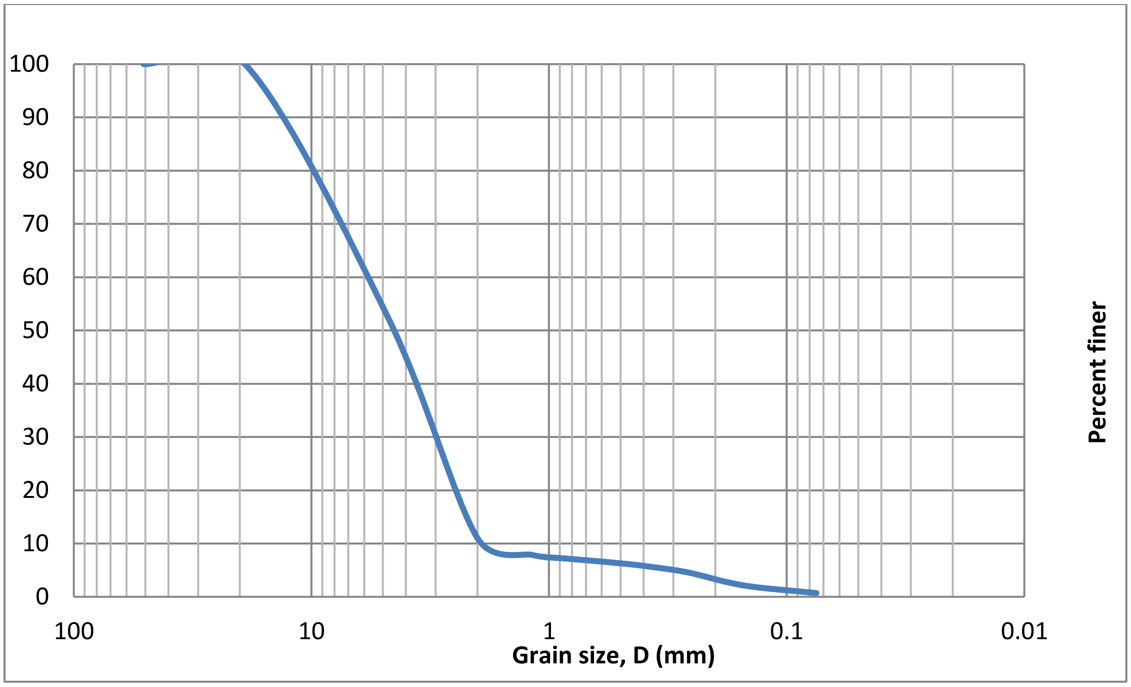


Figure 44: Particle Size Distribution for Limestone Screenings

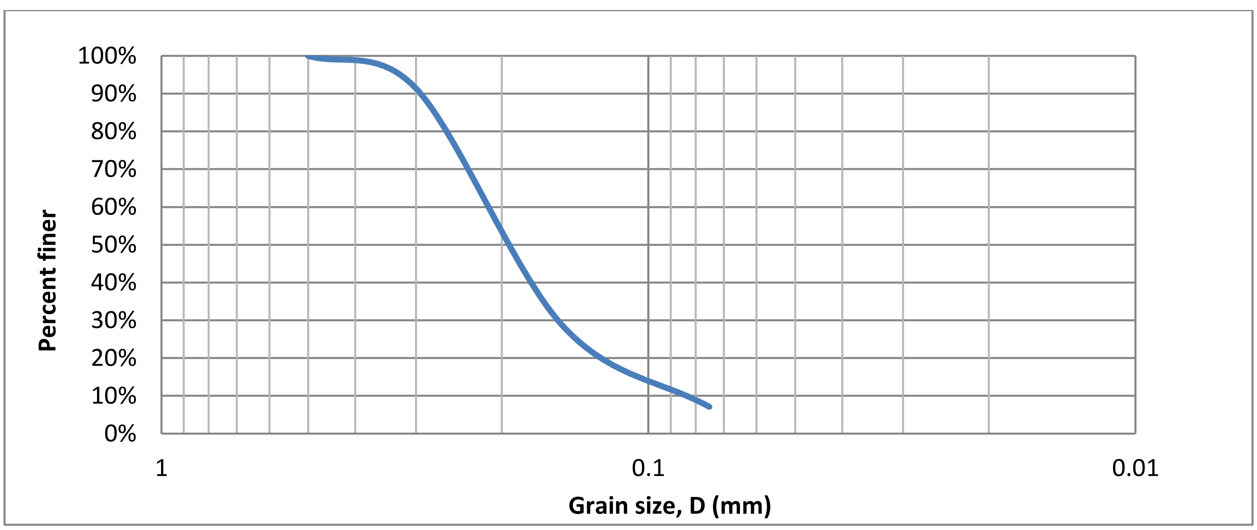


Figure 45: Particle Size Distribution for AASHTO A-3 sand with 7.1% silt/clay

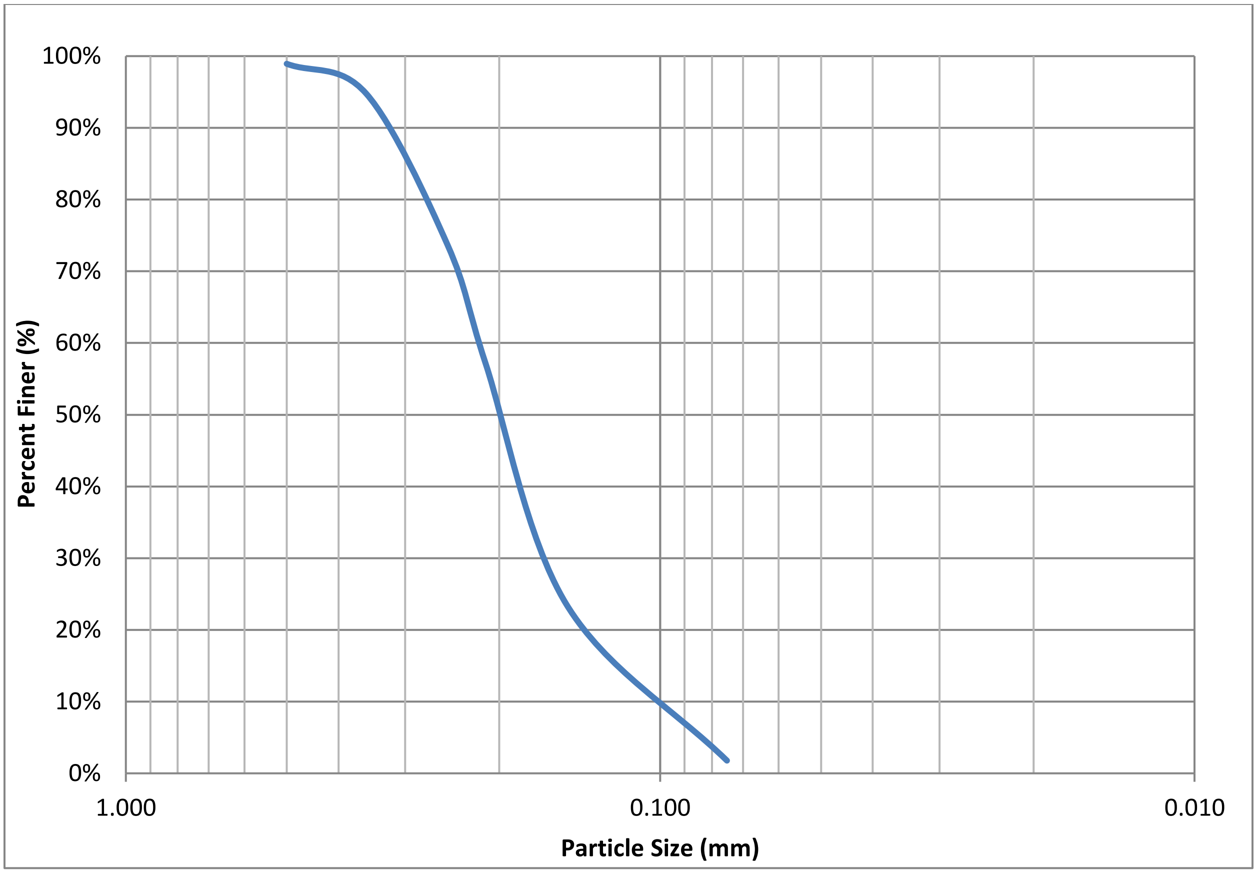


Figure 46: Particle Size Distribution for AASHTO A-3 sand with 1.8% silt/clay

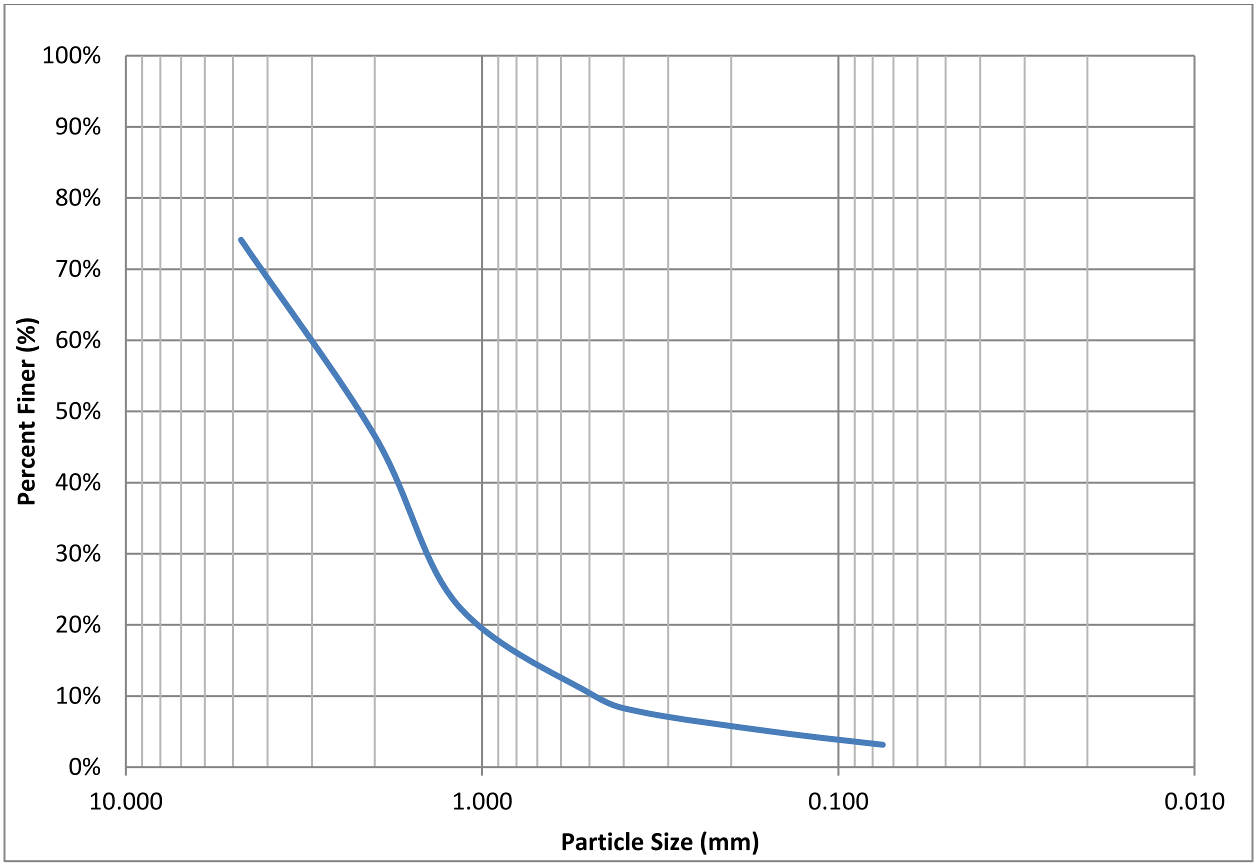


Figure 47: Particle Size Distribution for BAM #1

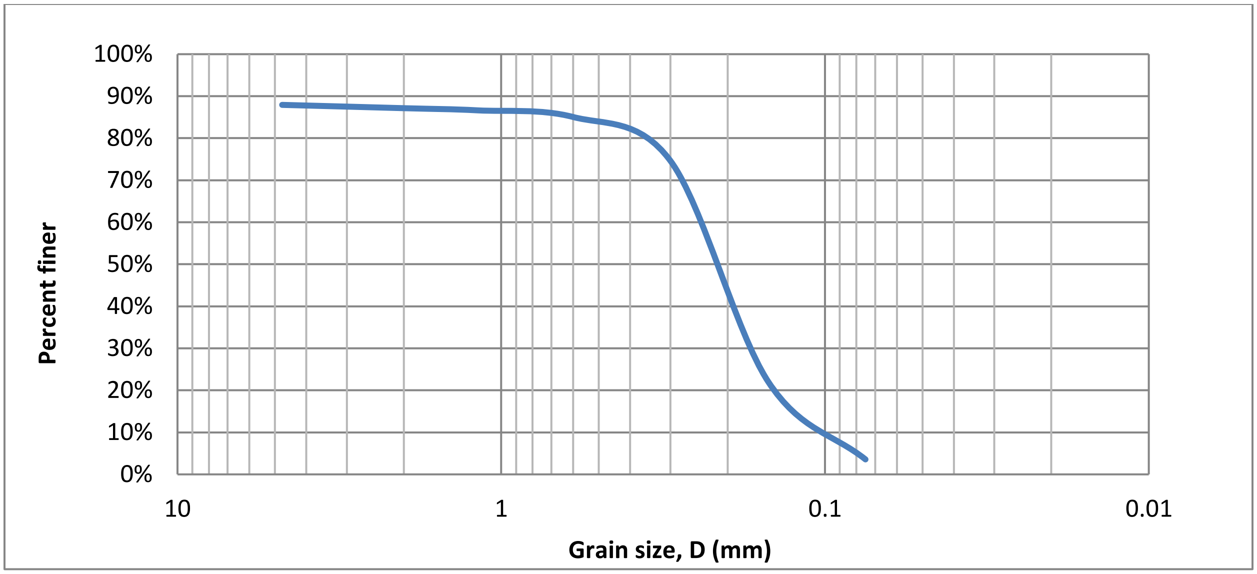


Figure 48: Particle Size Distribution for BAM #2

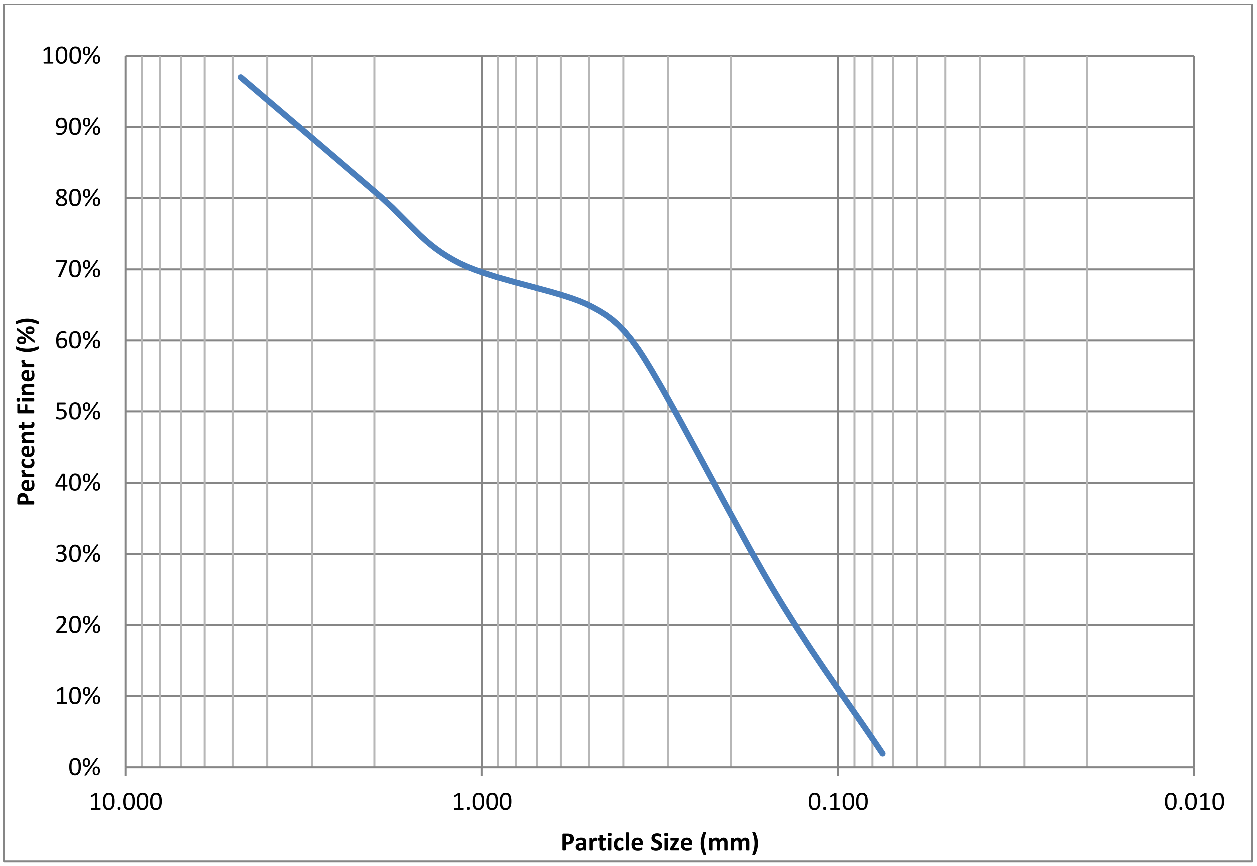


Figure 49: Particle Size Distribution for BAM #3

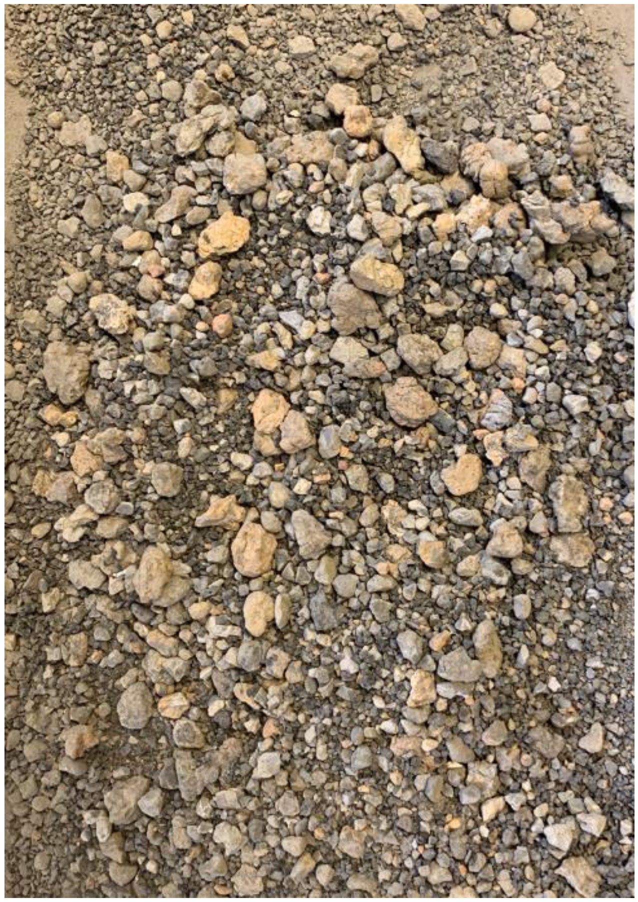


Figure 50: Photograph of BAM #1

Figure 51: Photograph of BAM #2

Figure 52: Photograph of BAM #3

APPENDIX J
INFLUENT NITRITE TO NO_X RATIO

Table 61: Influent Nitrite and Total NOx

Date	Influent for which Columns	NOx (mg/L as N)	NO_2^- (mg/L as N)
4/9/2013	A & B	0.0675	0.0072
4/26/2013	A & B	0.0908	0.0079
4/30/2013	A & B	0.1367	0.0060
5/1/2013	A & B	0.2125	0.0060
5/7/2013	A & B	0.1190	0.0067
4/9/2013	C	0.0625	0.0075
4/20/2013	C	0.1162	0.0040
4/26/2013	C	0.1096	0.0070

Mean	0.1143	0.0065
Standard Deviation	0.0472	0.0012

NO_2^- to NOx ratio	5.70%

NOx concentration was determined using HACH® Method 8192: Nitrate, Low Range. A HACH® DR 5000 Spectrophotometer was used. This method measures nitrate and nitrite together, yielding a NOx concentration.

NO_2^- was measured using HACH® Method 8507: Nitrite, Low Range. A HACH® DR 5000 Spectrophotometer was used.

APPENDIX K
DERIVATION OF EQUATIONS

Combined Decrease of Both Organic Nitrogen and Ammonia

The following is the derivation of the *combined decrease of both organic nitrogen and ammonia*. This value was used as a component of Equation (11). This decrease is due to both biological and physical/chemical processes. Organic nitrogen and ammonia are together referred to as Total Kjeldahl Nitrogen (TKN) [139]. Organic nitrogen is any form of nitrogen that is bound to carbon and includes, but is not limited to, amino acids, amino sugars, and proteins. Organic nitrogen is calculated as total nitrogen minus ammonia and NOx [139].

$$Combined\ decrease\ of\ organic\ nitrogen\ and\ ammonia$$
$$= (NH_{3_{Influent}} + Organic\ N_{Influent}) - (NH_{3_{Effluent}} + Organic\ N_{Effluent})$$

$$Combined\ decrease\ of\ organic\ nitrogen\ and\ ammonia$$
$$= \left(NH_{3_{Influent}} - NH_{3_{Effluent}}\right) + (Organic\ N_{Influent} - Organic\ N_{Effluent})$$

Where Organic Nitrogen = TN – NH_3 - NOx

$$Combined\ reduction\ of\ organic\ nitrogen\ and\ ammonia$$
$$= \left(NH_{3_{Influent}} - NH_{3_{Effluent}}\right)$$
$$+ \left[(TN - NH_3 - NO_X)_{Influent} - (TN - NH_3 - NO_X)_{Effluent}\right]$$

$$Combined\ reduction\ of\ organic\ nitrogen\ and\ ammonia$$
$$= NH_{3_{Influent}} - NH_{3_{Effluent}} + TN_{Influent} - TN_{Effluent} - NH_{3_{Influent}}$$
$$- NO_{X_{Influent}} + NH_{3_{Effluent}} + NO_{X_{Effluent}}$$

$$Combined\ reduction\ of\ organic\ nitrogen\ and\ ammonia$$
$$= TN_{Influent} - TN_{Effluent} - NO_{X_{Influent}} + NO_{X_{Effluent}}$$

$$Combined\ reduction\ of\ organic\ nitrogen\ and\ ammonia$$

$$= \left(NO_{X_{Effluent}} - NO_{X_{Influent}}\right) - \left(TN_{Effluent} - TN_{Influent}\right)$$

Where Δ = Effluent – Influent

$$\boxed{Combined\ reduction\ of\ organic\ nitrogen\ and\ ammonia = \Delta NO_X - \Delta TN}$$

APPENDIX L
HPC DATA

Table 62: HPC DATA – BAM #1, 22-minute EBCT

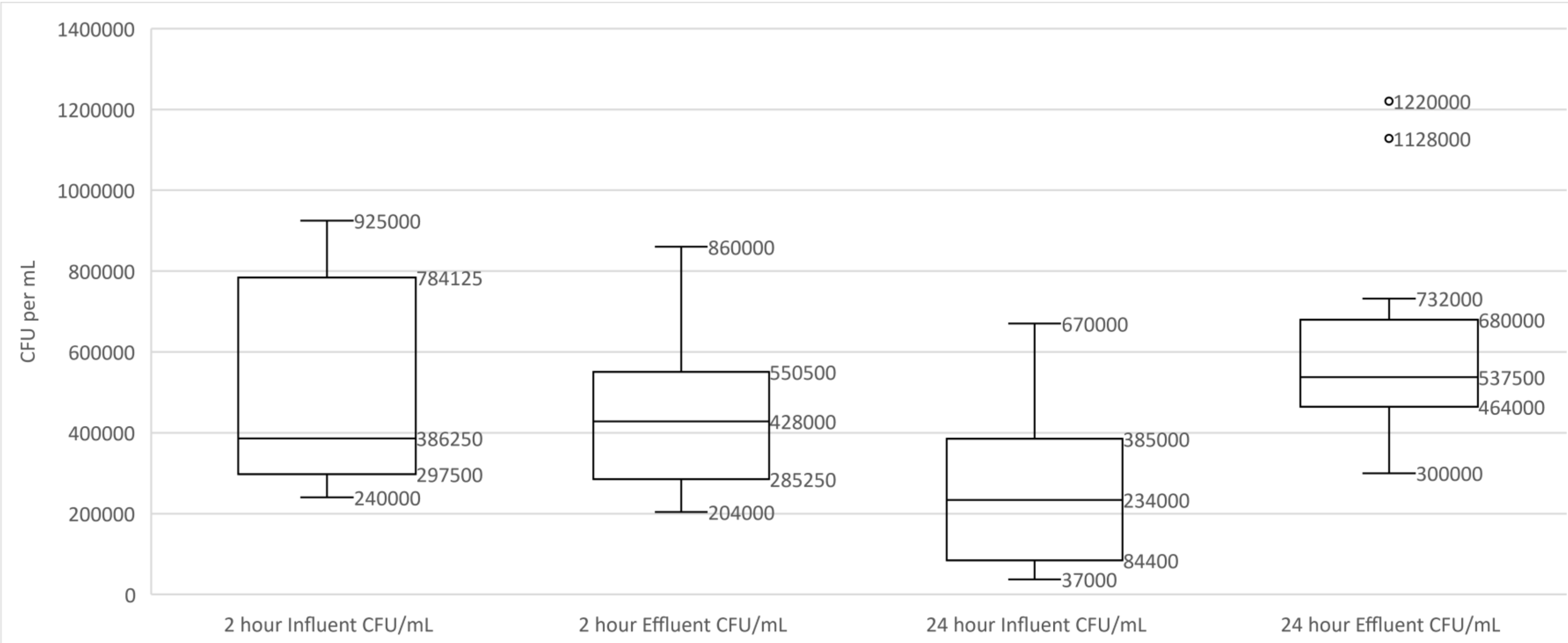
Columns Run Date	Approximate Flow Duration (hours)	Column Media #	Column Type	Influent CFU/mL	Effluent CFU/mL
8/7/2013	2	1	A	294000	230000
8/7/2013	2	1	B	294000	246000
8/15/2013	2	1	A	308000	262000
8/15/2013	2	1	B	308000	204000
9/27/2013	2	1	A	808000	492000
9/27/2013	2	1	B	808000	436000
10/4/2013	2	1	A	712500	860000
10/4/2013	2	1	B	712500	712500
10/18/2013	2	1	A	240000	570000
10/18/2013	2	1	B	240000	355000
10/25/2013	2	1	A	397500	460000
10/25/2013	2	1	B	397500	405000
11/1/2013	2	1	A	375000	400000
11/1/2013	2	1	B	375000	420000
11/8/2013	2	1	A	925000	640000
11/8/2013	2	1	B	925000	455000
			MEDIAN	386250	428000

Note: 2 hour flow duration is 22-minute EBCT

Table 63: HPC DATA – BAM #1, 220-minute EBCT

Columns Run Date	Approximate Flow Duration (hours)	Column Media #	Column Type	Influent CFU/mL	Effluent CFU/mL
7/24/2013	24	1	A	670000	442000
9/3/2013	24	1	A	234000	732000
9/3/2013	24	1	B	234000	464000
9/24/2013	24	1	A	84400	1128000
9/24/2013	24	1	B	84400	648000
10/1/2013	24	1	A	280000	495000
10/1/2013	24	1	B	280000	300000
10/15/2013	24	1	A	180000	680000
10/15/2013	24	1	B	180000	397500
10/29/2013	24	1	A	385000	510000
10/29/2013	24	1	B	385000	537500
11/5/2013	24	1	A	37000	1220000
11/5/2013	24	1	B	37000	650000
11/12/2013	24	1	A	427500	520000
11/12/2013	24	1	B	427500	632500
			MEDIAN	234000	537500

Note: 24 hour flow duration is 220-minute EBCT



Note:
•2-hour storm event is 22-minute EBCT
•24-hour storm event is 220-minute EBCT

Figure 53: HPC – BAM #1, Box & Whisker Plot

Table 64: HPC DATA – BAM #2, 22-minute EBCT

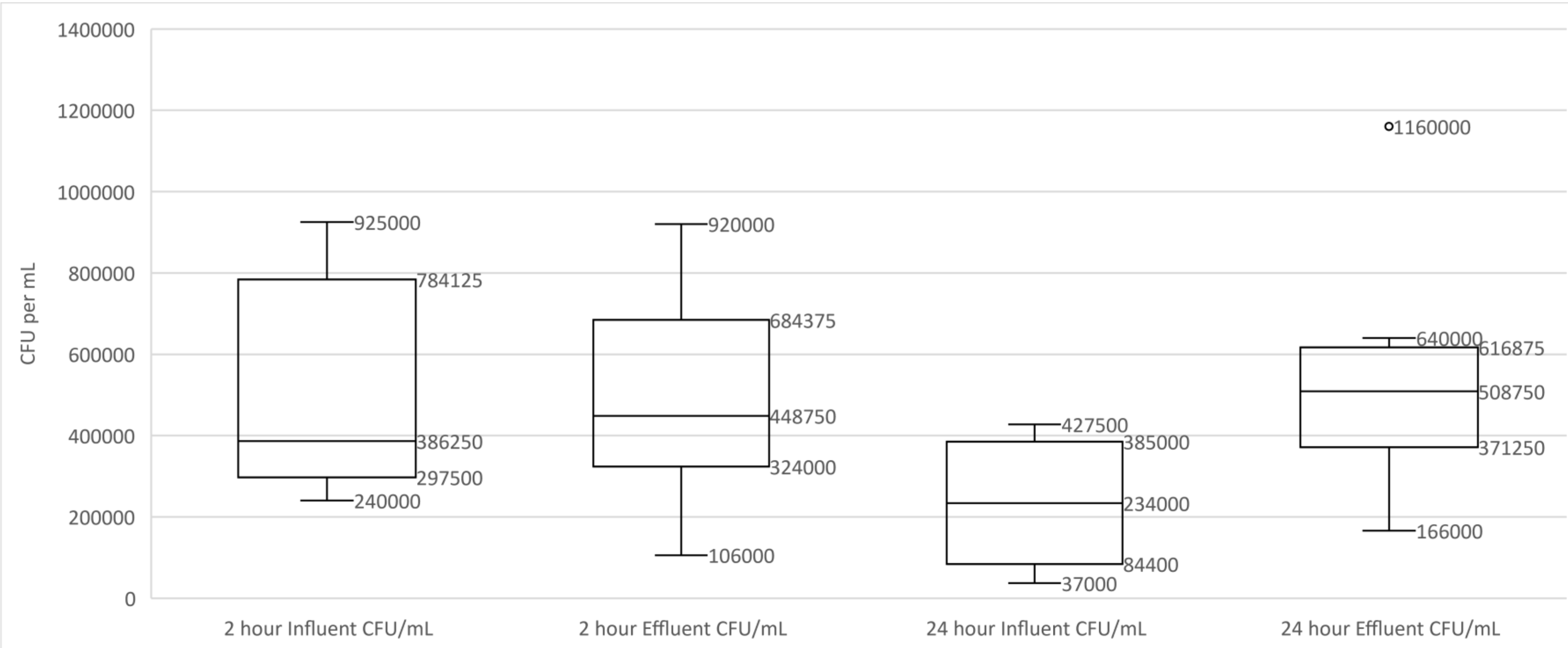
Columns Run Date	Approximate Flow Duration (hours)	Column Media #	Column Type	Influent CFU/mL	Effluent CFU/mL
8/7/2013	2	2	A	294000	106000
8/7/2013	2	2	B	294000	320000
8/15/2013	2	2	A	308000	336000
8/15/2013	2	2	B	308000	307000
9/27/2013	2	2	A	808000	920000
9/27/2013	2	2	B	808000	632000
10/4/2013	2	2	A	712500	912500
10/4/2013	2	2	B	712500	652500
10/18/2013	2	2	A	240000	342500
10/18/2013	2	2	B	240000	287500
10/25/2013	2	2	A	397500	575000
10/25/2013	2	2	B	397500	915000
11/1/2013	2	2	A	375000	477500
11/1/2013	2	2	B	375000	695000
11/8/2013	2	2	A	925000	420000
11/8/2013	2	2	B	925000	360000
			MEDIAN	386250	448750

Note: 2 hour flow duration is 22-minute EBCT

Table 65: HPC DATA – BAM #2, 220-minute EBCT

Columns Run Date	Approximate Flow Duration (hours)	Column Media #	Column Type	Influent CFU/mL	Effluent CFU/mL
9/3/2013	24	2	A	234000	166000
9/3/2013	24	2	B	234000	328000
9/24/2013	24	2	A	84400	1160000
9/24/2013	24	2	B	84400	580000
10/1/2013	24	2	A	280000	345000
10/1/2013	24	2	B	280000	640000
10/15/2013	24	2	A	180000	380000
10/15/2013	24	2	B	180000	610000
10/29/2013	24	2	A	385000	467500
10/29/2013	24	2	B	385000	550000
11/5/2013	24	2	A	37000	637500
11/5/2013	24	2	B	37000	585000
11/12/2013	24	2	A	427500	412500
11/12/2013	24	2	B	427500	407500
			MEDIAN	234000	508750

Note: 24 hour flow duration is 220-minute EBCT



Note:
•2-hour storm event is 22-minute EBCT
•24-hour storm event is 220-minute EBCT

Figure 54: HPC – BAM #2, Box & Whisker Plot

Table 66: HPC DATA – BAM #3, 22-minute EBCT

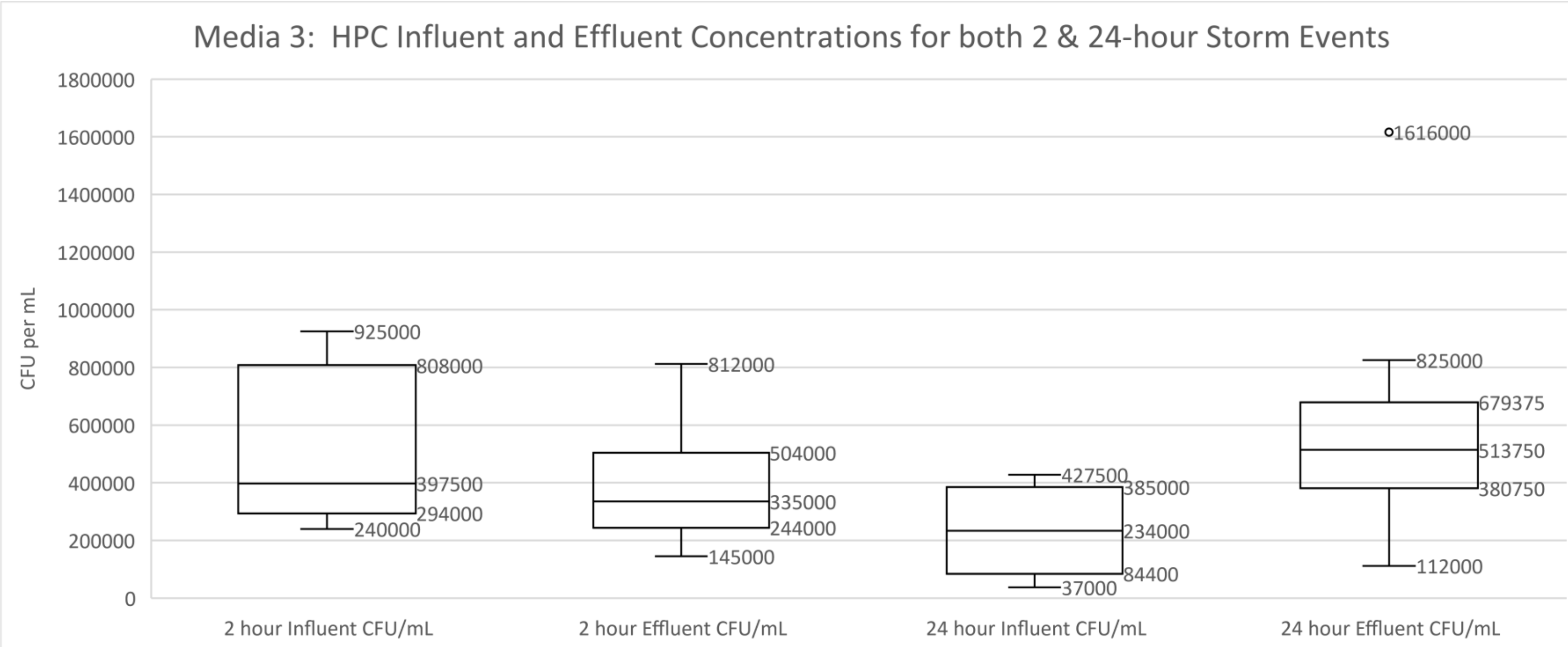
Columns Run Date	Approximate Flow Duration (hours)	Column Media #	Column Type	Influent CFU/mL	Effluent CFU/mL
8/7/2013	2	3	A	294000	244000
8/7/2013	2	3	B	294000	160000
8/15/2013	2	3	A	308000	408000
8/15/2013	2	3	B	308000	312000
9/27/2013	2	3	A	808000	504000
9/27/2013	2	3	B	808000	812000
10/4/2013	2	3	A	712500	785000
10/4/2013	2	3	B	712500	762500
10/18/2013	2	3	A	240000	237500
10/18/2013	2	3	B	240000	145000
10/25/2013	2	3	A	397500	447500
10/25/2013	2	3	B	397500	325000
11/1/2013	2	3	A	375000	335000
11/8/2013	2	3	A	925000	260000
11/8/2013	2	3	B	925000	475000
			MEDIAN	397500	335000

Note: 2 hour flow duration is 22-minute EBCT

Table 67: HPC DATA – BAM #3, 220-minute EBCT

Columns Run Date	Approximate Flow Duration (hours)	Column Media #	Column Type	Influent CFU/mL	Effluent CFU/mL
9/3/2013	24	3	A	234000	112000
9/3/2013	24	3	B	234000	308000
9/24/2013	24	3	A	84400	564000
9/24/2013	24	3	B	84400	1616000
10/1/2013	24	3	A	280000	535000
10/1/2013	24	3	B	280000	825000
10/15/2013	24	3	A	180000	492500
10/15/2013	24	3	B	180000	640000
10/29/2013	24	3	A	385000	300000
10/29/2013	24	3	B	385000	480000
11/5/2013	24	3	A	37000	450000
11/5/2013	24	3	B	37000	797500
11/12/2013	24	3	A	427500	610000
11/12/2013	24	3	B	427500	405000
			MEDIAN	234000	513750

Note: 24 hour flow duration is 220-minute EBCT



Note:
•2-hour storm event is 22-minute EBCT
•24-hour storm event is 220-minute EBCT

Figure 55: HPC – BAM #3, Box & Whisker Plot

APPENDIX M
TOTAL COLIFORM DATA

Table 68: Total Coliform Data – BAM #1, 22-minute EBCT

Columns Run Date	Approximate Flow Duration (hours)	Column Media #	Column Type	Influent Total Coliform: Most Probable Number per 100mL	Effluent Total Coliform: Most Probable Number per 100mL
7/31/2013	2	1	A	14387	14387
8/7/2013	2	1	A	6695	1596
8/7/2013	2	1	B	6695	1731
8/7/2013	2	1	C	7057	1435
11/22/2013	2	1	A	24890	8197
11/22/2013	2	1	C	24890	6631
12/11/2013	2	1	A	306	<100
12/11/2013	2	1	C	306	304

Note: 2 hour flow duration is 22-minute EBCT

Table 69: Total Coliform Data – BAM #1, 220-minute EBCT

Columns Run Date	Approximate Flow Duration (hours)	Column Media #	Column Type	Influent Total Coliform: Most Probable Number per 100mL	Effluent Total Coliform: Most Probable Number per 100mL
11/19/2013	24	1	A	516	<100
11/19/2013	24	1	C	516	202
12/12/2013	24	1	A	6332	306
12/12/2013	24	1	C	6332	100

Note: 24 hour flow duration is 220-minute EBCT

Table 70: Total Coliform Data – BAM #2, 22-minute EBCT

Columns Run Date	Approximate Flow Duration (hours)	Column Media #	Column Type	Influent - Total Coliform: Most Probable Number per 100mL	Effluent - Total Coliform: Most Probable Number per 100mL
7/31/2013	2	2	C	14387	6828
8/7/2013	2	2	A	6695	2157
8/7/2013	2	2	C	7057	3684
11/22/2013	2	2	A	24890	9881
11/22/2013	2	2	C	24890	31694
12/11/2013	2	2	A	306	201
12/11/2013	2	2	C	306	844

Note: 2 hour flow duration is 22-minute EBCT

Table 71: Total Coliform Data – BAM #2, 220-minute EBCT

Columns Run Date	Approximate Flow Duration (hours)	Column Media #	Column Type	Influent - Total Coliform: Most Probable Number per 100mL	Effluent - Total Coliform: Most Probable Number per 100mL
11/19/2013	24	2	A	516	306
11/19/2013	24	2	C	516	626
12/12/2013	24	2	A	6332	100
12/12/2013	24	2	C	6332	202

Note: 24 hour flow duration is 220-minute EBCT

Table 72: Total Coliform Data – BAM #3, 22-minute EBCT

Columns Run Date	Approximate Flow Duration (hours)	Column Media #	Column Type	Influent - Total Coliform: Most Probable Number per 100mL	Effluent - Total Coliform: Most Probable Number per 100mL
8/7/2013	2	3	A	6695	4195
8/7/2013	2	3	C	7057	1989
11/22/2013	2	3	A	24890	6828
11/22/2013	2	3	C	24890	2847
12/11/2013	2	3	A	306	100
12/11/2013	2	3	C	306	409

Note: 2 hour flow duration is 22-minute EBCT

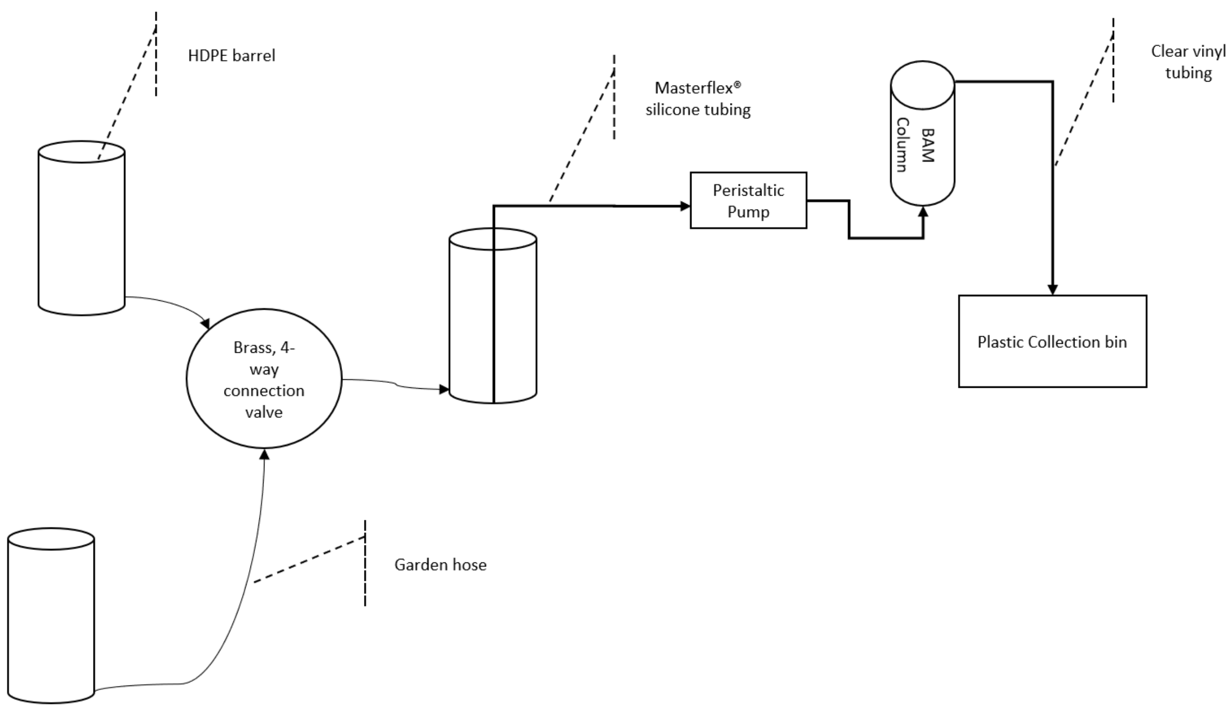
Table 73: Total Coliform Data – BAM #3, 220-minute EBCT

Columns Run Date	Approximate Flow Duration (hours)	Column Media #	Column Type	Influent - Total Coliform: Most Probable Number per 100mL	Effluent - Total Coliform: Most Probable Number per 100mL
11/19/2013	24	3	A	516	306
11/19/2013	24	3	C	516	100
12/12/2013	24	3	A	6332	100
12/12/2013	24	3	C	6332	1967

Note: 24 hour flow duration is 220-minute EBCT

APPENDIX N
COLUMN STUDY-EXPERIMENTAL SETUP

A and B columns were fed from the same influent barrels prior to 11/19/2013. From 11/19/2013 till end of research, B columns used separate influent barrels because the antibiotic Vancomycin was added to the B column influent. C columns were fed from influent barrels just for them because C column influent contained the nitrification inhibitor 2-Imidazolidinethione. The barrels were made of high density polyethylene (HDPE) and were connected in parallel to achieve the needed volume of water; the number of barrels varied depending on influent volume requirement. A diagram of the general column study system design is presented in Figure 56. Figure 57 shows the columns setup.



Note: Number of barrels and number of-way connection valves varied depending on influent volume requirements.

Figure 56: General Column Study System Design

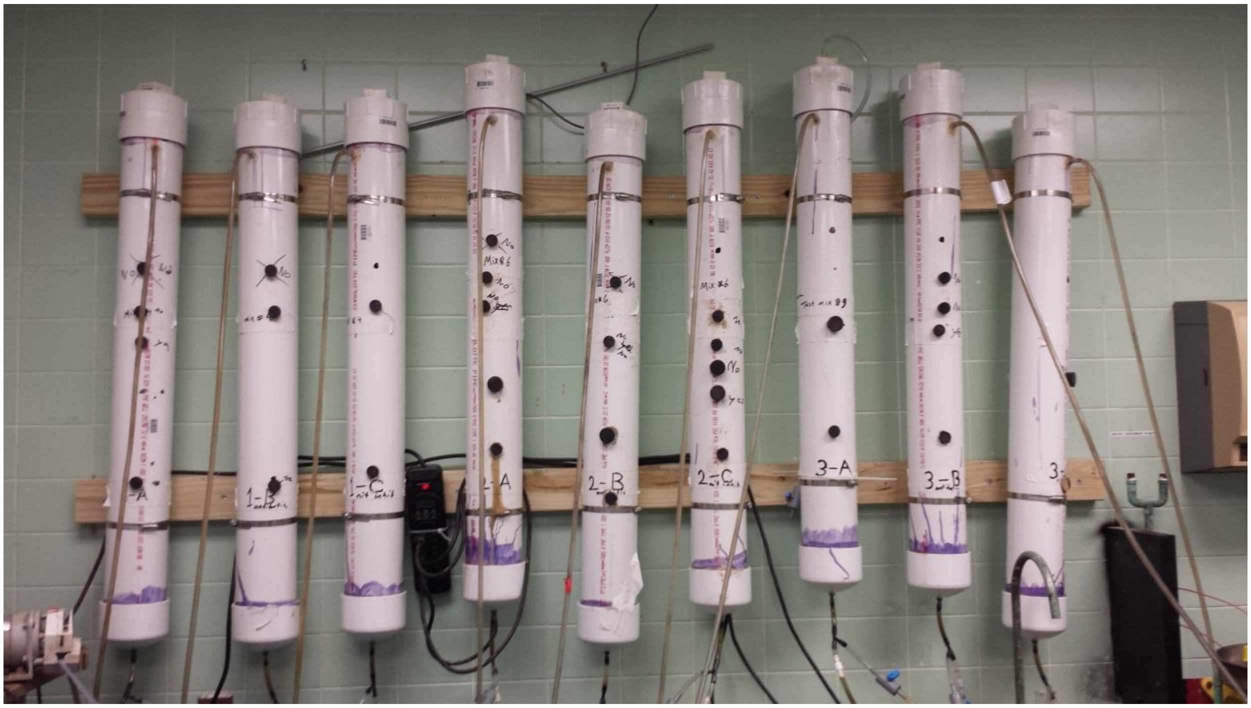


Figure 57: Column setup

APPENDIX O
TYPE OF RUN (SAMPLING OR BLANK) AND FLOW RATE

The Columns were run three times per week with an approximate 2-hour (120 minute) duration and once a week with an approximately 24-hour (1440 minute) duration. Sampling occurred during one of the 2-hour duration events per week and each 24-hour event per week, once consistent sampling began. The dates of each Column run event, whether it was a blank or sample, and the mass of water collected is presented in Table 74. Additionally, it is shown in Table 74 if there were antibiotics in the B column. Data from columns containing antibiotics was not used in the nitrogen, phosphorus, or bacterial pathogen analyses. For the nitrogen mass balance, only data after 9/24/2013 was considered due to the system not yet being in steady state in terms of nitrogen performance prior to that. Phosphorus analysis began on 5/1/2013 and continued till the end of sampling on 12/12/2013. Phosphorus data analysis was done on the A columns and the B columns that did not have antibiotics (pre 11/19/2013). The dates in Table 74 can be matched with the dates of the laboratory data results in APPENDIX B.

Table 74: Type of Run, Duration, & Mass of Effluent Water Collected

Columns Run Date	Type of Run	BAM #	Column Type	Antibiotic	Start Time	End Time	Exact Flow duration (min)	Mass of Water in Basin (kg)
4/1/2013	blank	1	A	na	4/1/2013 13:56	4/1/2013 16:13	137	28.01
4/1/2013	blank	1	B	no	4/1/2013 13:56	4/1/2013 16:13	137	41.76
4/1/2013	blank	1	C	na	4/1/2013 13:56	4/1/2013 16:13	137	40.46
4/1/2013	blank	2	A	na	4/1/2013 13:56	4/1/2013 16:13	137	20.90
4/1/2013	blank	2	B	no	4/1/2013 13:56	4/1/2013 16:13	137	19.85
4/1/2013	blank	2	C	na	4/1/2013 13:56	4/1/2013 16:13	137	25.88
4/1/2013	blank	3	A	na	4/1/2013 13:56	4/1/2013 16:13	137	26.59
4/1/2013	blank	3	B	no	4/1/2013 13:56	4/1/2013 16:13	137	39.99
4/1/2013	blank	3	C	na	4/1/2013 13:56	4/1/2013 16:13	137	40.32
4/5/2013	blank	1	A	na	4/5/2013 13:24	4/5/2013 15:48	144	17.77
4/5/2013	blank	1	B	no	4/5/2013 13:24	4/5/2013 15:48	144	33.05
4/5/2013	blank	1	C	na	4/5/2013 13:24	4/5/2013 15:48	144	32.51
4/5/2013	blank	2	A	na	4/5/2013 13:24	4/5/2013 15:48	144	27.85
4/5/2013	blank	2	B	no	4/5/2013 13:24	4/5/2013 15:48	144	23.65
4/5/2013	blank	2	C	na	4/5/2013 13:24	4/5/2013 15:48	144	30.05
4/5/2013	blank	3	A	na	4/5/2013 13:24	4/5/2013 15:48	144	32.07
4/5/2013	blank	3	B	no	4/5/2013 13:24	4/5/2013 15:48	144	32.44
4/5/2013	blank	3	C	na	4/5/2013 13:24	4/5/2013 15:48	144	33.13
4/6/2013	blank	1	A	na	4/6/2013 16:20	4/6/2013 18:25	125	8.87
4/6/2013	blank	1	B	no	4/6/2013 16:20	4/6/2013 18:25	125	25.82

Columns Run Date	Type of Run	BAM #	Column Type	Antibiotic	Start Time	End Time	Exact Flow duration (min)	Mass of Water in Basin (kg)
4/6/2013	blank	1	C	na	4/6/2013 16:20	4/6/2013 18:25	125	25.16
4/6/2013	blank	2	A	na	4/6/2013 16:20	4/6/2013 18:25	125	24.22
4/6/2013	blank	2	B	no	4/6/2013 16:20	4/6/2013 18:25	125	20.68
4/6/2013	blank	2	C	na	4/6/2013 16:20	4/6/2013 18:25	125	26.61
4/6/2013	blank	3	A	na	4/6/2013 16:20	4/6/2013 18:25	125	28.79
4/6/2013	blank	3	B	no	4/6/2013 16:20	4/6/2013 18:25	125	27.71
4/6/2013	blank	3	C	na	4/6/2013 16:20	4/6/2013 18:25	125	28.48
4/9/2013	sample	1	A	na	4/9/2013 15:30	4/9/2013 17:42	132	7.18
4/9/2013	sample	1	B	no	4/9/2013 15:30	4/9/2013 17:42	132	30.85
4/9/2013	sample	1	C	na	4/9/2013 15:30	4/9/2013 17:42	132	29.75
4/9/2013	sample	2	A	na	4/9/2013 15:30	4/9/2013 17:42	132	16.61
4/9/2013	sample	2	B	no	4/9/2013 15:30	4/9/2013 17:42	132	16.48
4/9/2013	sample	2	C	na	4/9/2013 15:30	4/9/2013 17:42	132	29.97
4/9/2013	sample	3	A	na	4/9/2013 15:30	4/9/2013 17:42	132	30.64
4/9/2013	sample	3	B	no	4/9/2013 15:30	4/9/2013 17:42	132	31.39
4/9/2013	sample	3	C	na	4/9/2013 15:30	4/9/2013 17:42	132	32.60
4/10/2013	blank	1	A	na	4/10/2013 11:08	4/10/2013 13:19	131	1.57
4/10/2013	blank	1	B	no	4/10/2013 11:08	4/10/2013 13:19	131	31.23
4/10/2013	blank	1	C	na	4/10/2013 11:08	4/10/2013 13:19	131	30.22
4/10/2013	blank	2	A	na	4/10/2013 11:08	4/10/2013 13:19	131	18.20
4/10/2013	blank	2	B	no	4/10/2013 11:08	4/10/2013 13:19	131	14.03

Columns Run Date	Type of Run	BAM #	Column Type	Antibiotic	Start Time	End Time	Exact Flow duration (min)	Mass of Water in Basin (kg)
4/10/2013	blank	2	C	na	4/10/2013 11:08	4/10/2013 13:19	131	29.35
4/10/2013	blank	3	A	na	4/10/2013 11:08	4/10/2013 13:19	131	30.49
4/10/2013	blank	3	B	no	4/10/2013 11:08	4/10/2013 13:19	131	29.80
4/10/2013	blank	3	C	na	4/10/2013 11:08	4/10/2013 13:19	131	30.65
4/12/2013	blank	1	A	na	4/12/2013 15:35	4/12/2013 17:38	123	15.87
4/12/2013	blank	1	B	no	4/12/2013 15:35	4/12/2013 17:38	123	28.77
4/12/2013	blank	1	C	na	4/12/2013 15:35	4/12/2013 17:38	123	28.56
4/12/2013	blank	2	A	na	4/12/2013 15:35	4/12/2013 17:38	123	16.73
4/12/2013	blank	2	B	no	4/12/2013 15:35	4/12/2013 17:38	123	11.88
4/12/2013	blank	2	C	na	4/12/2013 15:35	4/12/2013 17:38	123	27.47
4/12/2013	blank	3	A	na	4/12/2013 15:35	4/12/2013 17:38	123	28.69
4/12/2013	blank	3	B	no	4/12/2013 15:35	4/12/2013 17:38	123	27.55
4/12/2013	blank	3	C	na	4/12/2013 15:35	4/12/2013 17:38	123	27.41
4/15/2013	blank	1	A	na	4/15/2013 15:06	4/15/2013 17:09	123	13.88
4/15/2013	blank	1	B	no	4/15/2013 15:06	4/15/2013 17:09	123	27.15
4/15/2013	blank	1	C	na	4/15/2013 15:06	4/15/2013 17:09	123	26.44
4/15/2013	blank	2	A	na	4/15/2013 15:06	4/15/2013 17:09	123	20.29
4/15/2013	blank	2	B	no	4/15/2013 15:06	4/15/2013 17:09	123	10.02
4/15/2013	blank	2	C	na	4/15/2013 15:06	4/15/2013 17:09	123	26.15
4/15/2013	blank	3	A	na	4/15/2013 15:06	4/15/2013 17:09	123	27.89
4/15/2013	blank	3	B	no	4/15/2013 15:06	4/15/2013 17:09	123	28.54

Columns Run Date	Type of Run	BAM #	Column Type	Antibiotic	Start Time	End Time	Exact Flow duration (min)	Mass of Water in Basin (kg)
4/15/2013	blank	3	C	na	4/15/2013 15:06	4/15/2013 17:09	123	28.10
4/18/2013	sample	1	A	na	4/18/2013 13:40	4/18/2013 15:52	132	13.44
4/18/2013	sample	1	B	no	4/18/2013 13:40	4/18/2013 15:52	132	28.72
4/18/2013	sample	1	C	na	4/18/2013 13:40	4/18/2013 15:52	132	28.57
4/18/2013	sample	2	A	na	4/18/2013 13:40	4/18/2013 15:52	132	21.81
4/18/2013	sample	2	B	no	4/18/2013 13:40	4/18/2013 15:52	132	23.69
4/18/2013	sample	2	C	na	4/18/2013 13:40	4/18/2013 15:52	132	28.35
4/18/2013	sample	3	A	na	4/18/2013 13:40	4/18/2013 15:52	132	29.57
4/18/2013	sample	3	B	no	4/18/2013 13:40	4/18/2013 15:52	132	29.91
4/18/2013	sample	3	C	na	4/18/2013 13:40	4/18/2013 15:52	132	29.52
4/25/2013	sample	1	A	na	4/25/2013 13:50	4/25/2013 15:55	125	24.03
4/25/2013	sample	1	B	no	4/25/2013 13:50	4/25/2013 15:55	125	27.27
4/25/2013	sample	1	C	na	4/25/2013 13:50	4/25/2013 15:55	125	27.37
4/25/2013	sample	2	A	na	4/25/2013 13:50	4/25/2013 15:55	125	17.53
4/25/2013	sample	2	B	no	4/25/2013 13:50	4/25/2013 15:55	125	21.91
4/25/2013	sample	2	C	na	4/25/2013 13:50	4/25/2013 15:55	125	26.09
4/25/2013	sample	3	A	na	4/25/2013 13:50	4/25/2013 15:55	125	27.76
4/25/2013	sample	3	B	no	4/25/2013 13:50	4/25/2013 15:55	125	28.70
4/25/2013	sample	3	C	na	4/25/2013 13:50	4/25/2013 15:55	125	28.75
4/30/2013	sample	1	A	na	4/30/2013 9:38	4/30/2013 12:01	143	34.33
4/30/2013	sample	1	B	no	4/30/2013 9:38	4/30/2013 12:01	143	40.42

Columns Run Date	Type of Run	BAM #	Column Type	Antibiotic	Start Time	End Time	Exact Flow duration (min)	Mass of Water in Basin (kg)
4/30/2013	sample	1	C	na	4/30/2013 9:38	4/30/2013 12:01	143	39.97
4/30/2013	sample	2	A	na	4/30/2013 9:38	4/30/2013 12:01	143	22.20
4/30/2013	sample	2	B	no	4/30/2013 9:38	4/30/2013 12:01	143	25.31
4/30/2013	sample	2	C	na	4/30/2013 9:38	4/30/2013 12:01	143	39.70
4/30/2013	sample	3	A	na	4/30/2013 9:38	4/30/2013 12:01	143	40.08
4/30/2013	sample	3	B	no	4/30/2013 9:38	4/30/2013 12:01	143	40.80
4/30/2013	sample	3	C	na	4/30/2013 9:38	4/30/2013 12:01	143	41.77
5/1/2013	sample	1	A	na	5/1/2013 10:25	5/1/2013 12:50	145	25.66
5/1/2013	sample	1	B	no	5/1/2013 10:25	5/1/2013 12:50	145	32.44
5/1/2013	sample	1	C	na	5/1/2013 10:25	5/1/2013 12:50	145	31.80
5/1/2013	sample	2	A	na	5/1/2013 10:25	5/1/2013 12:50	145	14.64
5/1/2013	sample	2	B	no	5/1/2013 10:25	5/1/2013 12:50	145	12.31
5/1/2013	sample	2	C	na	5/1/2013 10:25	5/1/2013 12:50	145	30.68
5/1/2013	sample	3	A	na	5/1/2013 10:25	5/1/2013 12:50	145	32.68
5/1/2013	sample	3	B	no	5/1/2013 10:25	5/1/2013 12:50	145	33.04
5/1/2013	sample	3	C	na	5/1/2013 10:25	5/1/2013 12:50	145	33.40
5/7/2013	sample	1	A	na	5/7/2013 12:18	5/7/2013 14:20	122	22.47
5/7/2013	sample	1	B	no	5/7/2013 12:18	5/7/2013 14:20	122	26.98
5/7/2013	sample	1	C	na	5/7/2013 12:18	5/7/2013 14:20	122	26.33
5/7/2013	sample	2	A	na	5/7/2013 12:18	5/7/2013 14:20	122	6.24
5/7/2013	sample	2	B	no	5/7/2013 12:18	5/7/2013 14:20	122	8.21

Columns Run Date	Type of Run	BAM #	Column Type	Antibiotic	Start Time	End Time	Exact Flow duration (min)	Mass of Water in Basin (kg)
5/7/2013	sample	2	C	na	5/7/2013 12:18	5/7/2013 14:20	122	25.61
5/7/2013	sample	3	A	na	5/7/2013 12:18	5/7/2013 14:20	122	27.37
5/7/2013	sample	3	B	no	5/7/2013 12:18	5/7/2013 14:20	122	27.62
5/7/2013	sample	3	C	na	5/7/2013 12:18	5/7/2013 14:20	122	27.63
5/8/2013	blank	1	A	na	5/8/2013 14:17	5/8/2013 16:17	120	8.12
5/8/2013	blank	1	B	no	5/8/2013 14:17	5/8/2013 16:17	120	26.43
5/8/2013	blank	1	C	na	5/8/2013 14:17	5/8/2013 16:17	120	25.52
5/8/2013	blank	2	A	na	5/8/2013 14:17	5/8/2013 16:17	120	18.11
5/8/2013	blank	2	B	no	5/8/2013 14:17	5/8/2013 16:17	120	10.71
5/8/2013	blank	2	C	na	5/8/2013 14:17	5/8/2013 16:17	120	25.93
5/8/2013	blank	3	A	na	5/8/2013 14:17	5/8/2013 16:17	120	27.16
5/8/2013	blank	3	B	no	5/8/2013 14:17	5/8/2013 16:17	120	25.08
5/8/2013	blank	3	C	na	5/8/2013 14:17	5/8/2013 16:17	120	25.14
5/9/2013	blank	1	A	na	5/9/2013 12:05	5/9/2013 14:05	120	4.67
5/9/2013	blank	1	B	no	5/9/2013 12:05	5/9/2013 14:05	120	26.62
5/9/2013	blank	1	C	na	5/9/2013 12:05	5/9/2013 14:05	120	25.84
5/9/2013	blank	2	A	na	5/9/2013 12:05	5/9/2013 14:05	120	13.49
5/9/2013	blank	2	B	no	5/9/2013 12:05	5/9/2013 14:05	120	11.35
5/9/2013	blank	2	C	na	5/9/2013 12:05	5/9/2013 14:05	120	26.82
5/9/2013	blank	3	A	na	5/9/2013 12:05	5/9/2013 14:05	120	27.41
5/9/2013	blank	3	B	no	5/9/2013 12:05	5/9/2013 14:05	120	31.43

Columns Run Date	Type of Run	BAM #	Column Type	Antibiotic	Start Time	End Time	Exact Flow duration (min)	Mass of Water in Basin (kg)
5/9/2013	blank	3	C	na	5/9/2013 12:05	5/9/2013 14:05	120	32.35
6/4/2013	blank	1	A	na	6/4/2013 15:25	6/4/2013 17:41	136	26.06
6/4/2013	blank	1	B	no	6/4/2013 15:25	6/4/2013 17:41	136	30.75
6/4/2013	blank	1	C	na	6/4/2013 15:25	6/4/2013 17:41	136	28.82
6/4/2013	blank	2	A	na	6/4/2013 15:25	6/4/2013 17:41	136	30.24
6/4/2013	blank	2	B	no	6/4/2013 15:25	6/4/2013 17:41	136	30.69
6/4/2013	blank	2	C	na	6/4/2013 15:25	6/4/2013 17:41	136	30.53
6/4/2013	blank	3	A	na	6/4/2013 15:25	6/4/2013 17:41	136	29.23
6/4/2013	blank	3	B	no	6/4/2013 15:25	6/4/2013 17:41	136	32.49
6/4/2013	blank	3	C	na	6/4/2013 15:25	6/4/2013 17:41	136	32.59
6/6/2013	sample	1	A	na	6/6/2013 11:30	6/6/2013 13:50	140	26.75
6/6/2013	sample	1	B	no	6/6/2013 11:30	6/6/2013 13:50	140	31.06
6/6/2013	sample	1	C	na	6/6/2013 11:30	6/6/2013 13:50	140	30.63
6/6/2013	sample	2	A	na	6/6/2013 11:30	6/6/2013 13:50	140	32.01
6/6/2013	sample	2	B	no	6/6/2013 11:30	6/6/2013 13:50	140	30.66
6/6/2013	sample	2	C	na	6/6/2013 11:30	6/6/2013 13:50	140	29.69
6/6/2013	sample	3	A	na	6/6/2013 11:30	6/6/2013 13:50	140	33.41
6/6/2013	sample	3	B	no	6/6/2013 11:30	6/6/2013 13:50	140	33.54
6/6/2013	sample	3	C	na	6/6/2013 11:30	6/6/2013 13:50	140	30.09
6/12/2013	sample	1	A	na	6/12/2013 7:50	6/12/2013 10:15	145	26.42
6/12/2013	sample	1	B	no	6/12/2013 7:50	6/12/2013 10:15	145	32.10

Columns Run Date	Type of Run	BAM #	Column Type	Antibiotic	Start Time	End Time	Exact Flow duration (min)	Mass of Water in Basin (kg)
6/12/2013	sample	1	C	na	6/12/2013 7:50	6/12/2013 10:15	145	30.54
6/12/2013	sample	2	A	na	6/12/2013 7:50	6/12/2013 10:15	145	32.52
6/12/2013	sample	2	B	no	6/12/2013 7:50	6/12/2013 10:15	145	30.95
6/12/2013	sample	2	C	na	6/12/2013 7:50	6/12/2013 10:15	145	30.47
6/12/2013	sample	3	A	na	6/12/2013 7:50	6/12/2013 10:15	145	34.13
6/12/2013	sample	3	B	no	6/12/2013 7:50	6/12/2013 10:15	145	34.39
6/12/2013	sample	3	C	na	6/12/2013 7:50	6/12/2013 10:15	145	30.79
6/13/2013	sample	1	A	na	6/13/2013 13:00	6/13/2013 15:13	133	24.39
6/13/2013	sample	1	B	no	6/13/2013 13:00	6/13/2013 15:13	133	28.34
6/13/2013	sample	1	C	na	6/13/2013 13:00	6/13/2013 15:13	133	30.64
6/13/2013	sample	2	A	na	6/13/2013 13:00	6/13/2013 15:13	133	29.17
6/13/2013	sample	2	B	no	6/13/2013 13:00	6/13/2013 15:13	133	28.60
6/13/2013	sample	2	C	na	6/13/2013 13:00	6/13/2013 15:13	133	28.04
6/13/2013	sample	3	A	na	6/13/2013 13:00	6/13/2013 15:13	133	31.05
6/13/2013	sample	3	B	no	6/13/2013 13:00	6/13/2013 15:13	133	31.38
6/13/2013	sample	3	C	na	6/13/2013 13:00	6/13/2013 15:13	133	27.99
6/18/2013	blank	1	A	na	6/18/2013 9:47	6/18/2013 11:53	126	21.15
6/18/2013	blank	1	B	no	6/18/2013 9:47	6/18/2013 11:53	126	26.99
6/18/2013	blank	1	C	na	6/18/2013 9:47	6/18/2013 11:53	126	28.75
6/18/2013	blank	2	A	na	6/18/2013 9:47	6/18/2013 11:53	126	27.73
6/18/2013	blank	2	B	no	6/18/2013 9:47	6/18/2013 11:53	126	27.47

Columns Run Date	Type of Run	BAM #	Column Type	Antibiotic	Start Time	End Time	Exact Flow duration (min)	Mass of Water in Basin (kg)
6/18/2013	blank	2	C	na	6/18/2013 9:47	6/18/2013 11:53	126	26.94
6/18/2013	blank	3	A	na	6/18/2013 9:47	6/18/2013 11:53	126	29.44
6/18/2013	blank	3	B	no	6/18/2013 9:47	6/18/2013 11:53	126	29.44
6/18/2013	blank	3	C	na	6/18/2013 9:47	6/18/2013 11:53	126	26.15
6/20/2013	sample	1	A	na	6/20/2013 10:32	6/20/2013 12:50	138	23.44
6/20/2013	sample	1	B	no	6/20/2013 10:32	6/20/2013 12:50	138	29.44
6/20/2013	sample	1	C	na	6/20/2013 10:32	6/20/2013 12:50	138	30.93
6/20/2013	sample	2	A	na	6/20/2013 10:32	6/20/2013 12:50	138	29.68
6/20/2013	sample	2	B	no	6/20/2013 10:32	6/20/2013 12:50	138	29.89
6/20/2013	sample	2	C	na	6/20/2013 10:32	6/20/2013 12:50	138	29.09
6/20/2013	sample	3	A	na	6/20/2013 10:32	6/20/2013 12:50	138	33.99
6/20/2013	sample	3	B	no	6/20/2013 10:32	6/20/2013 12:50	138	30.44
6/20/2013	sample	3	C	na	6/20/2013 10:32	6/20/2013 12:50	138	31.49
6/24/2013	sample	1	A	na	6/24/2013 13:20	6/24/2013 15:50	150	25.15
6/24/2013	sample	1	B	no	6/24/2013 13:20	6/24/2013 15:50	150	31.99
6/24/2013	sample	1	C	na	6/24/2013 13:20	6/24/2013 15:50	150	33.28
6/24/2013	sample	2	A	na	6/24/2013 13:20	6/24/2013 15:50	150	31.29
6/24/2013	sample	2	B	no	6/24/2013 13:20	6/24/2013 15:50	150	32.34
6/24/2013	sample	2	C	na	6/24/2013 13:20	6/24/2013 15:50	150	31.42
6/24/2013	sample	3	A	na	6/24/2013 13:20	6/24/2013 15:50	150	37.10
6/24/2013	sample	3	B	no	6/24/2013 13:20	6/24/2013 15:50	150	35.46

Columns Run Date	Type of Run	BAM #	Column Type	Antibiotic	Start Time	End Time	Exact Flow duration (min)	Mass of Water in Basin (kg)
6/24/2013	sample	3	C	na	6/24/2013 13:20	6/24/2013 15:50	150	37.27
6/25/2013	sample	1	A	na	6/25/2013 12:34	6/26/2013 13:03	1469	16.69
6/25/2013	sample	1	B	no	6/25/2013 12:34	6/26/2013 13:03	1469	33.81
6/25/2013	sample	1	C	na	6/25/2013 12:34	6/26/2013 13:03	1469	34.76
6/25/2013	sample	2	A	na	6/25/2013 12:34	6/26/2013 13:03	1469	32.82
6/25/2013	sample	2	B	no	6/25/2013 12:34	6/26/2013 13:03	1469	35.42
6/25/2013	sample	2	C	na	6/25/2013 12:34	6/26/2013 13:03	1469	33.00
6/25/2013	sample	3	A	na	6/25/2013 12:34	6/26/2013 13:03	1469	36.96
6/25/2013	sample	3	B	no	6/25/2013 12:34	6/26/2013 13:03	1469	29.44
6/25/2013	sample	3	C	na	6/25/2013 12:34	6/26/2013 13:03	1469	34.37
6/27/2013	blank	1	A	na	6/27/2013 10:27	6/27/2013 12:37	130	23.21
6/27/2013	blank	1	B	no	6/27/2013 10:27	6/27/2013 12:37	130	29.26
6/27/2013	blank	1	C	na	6/27/2013 10:27	6/27/2013 12:37	130	29.81
6/27/2013	blank	2	A	na	6/27/2013 10:27	6/27/2013 12:37	130	30.50
6/27/2013	blank	2	B	no	6/27/2013 10:27	6/27/2013 12:37	130	28.60
6/27/2013	blank	2	C	na	6/27/2013 10:27	6/27/2013 12:37	130	28.32
6/27/2013	blank	3	A	na	6/27/2013 10:27	6/27/2013 12:37	130	30.45
6/27/2013	blank	3	B	no	6/27/2013 10:27	6/27/2013 12:37	130	30.40
6/27/2013	blank	3	C	na	6/27/2013 10:27	6/27/2013 12:37	130	30.77
7/2/2013	sample	1	A	na	7/2/2013 10:14	7/2/2013 12:33	139	32.39
7/2/2013	sample	1	B	no	7/2/2013 10:14	7/2/2013 12:33	139	31.61

Columns Run Date	Type of Run	BAM #	Column Type	Antibiotic	Start Time	End Time	Exact Flow duration (min)	Mass of Water in Basin (kg)
7/2/2013	sample	1	C	na	7/2/2013 10:14	7/2/2013 12:33	139	28.84
7/2/2013	sample	2	A	na	7/2/2013 10:14	7/2/2013 12:33	139	32.47
7/2/2013	sample	2	B	no	7/2/2013 10:14	7/2/2013 12:33	139	30.60
7/2/2013	sample	2	C	na	7/2/2013 10:14	7/2/2013 12:33	139	29.68
7/2/2013	sample	3	A	na	7/2/2013 10:14	7/2/2013 12:33	139	32.26
7/2/2013	sample	3	B	no	7/2/2013 10:14	7/2/2013 12:33	139	32.28
7/2/2013	sample	3	C	na	7/2/2013 10:14	7/2/2013 12:33	139	32.23
7/9/2013	blank	1	A	na	7/9/2013 12:25	7/9/2013 14:25	120	27.52
7/9/2013	blank	1	B	no	7/9/2013 12:25	7/9/2013 14:25	120	24.41
7/9/2013	blank	1	C	na	7/9/2013 12:25	7/9/2013 14:25	120	24.91
7/9/2013	blank	2	A	na	7/9/2013 12:25	7/9/2013 14:25	120	27.52
7/9/2013	blank	2	B	no	7/9/2013 12:25	7/9/2013 14:25	120	25.86
7/9/2013	blank	2	C	na	7/9/2013 12:25	7/9/2013 14:25	120	25.34
7/9/2013	blank	3	A	na	7/9/2013 12:25	7/9/2013 14:25	120	27.47
7/9/2013	blank	3	B	no	7/9/2013 12:25	7/9/2013 14:25	120	26.95
7/9/2013	blank	3	C	na	7/9/2013 12:25	7/9/2013 14:25	120	27.38
7/10/2013	blank	1	A	na	7/10/2013 9:25	7/10/2013 11:28	123	31.15
7/10/2013	blank	1	B	no	7/10/2013 9:25	7/10/2013 11:28	123	26.50
7/10/2013	blank	1	C	na	7/10/2013 9:25	7/10/2013 11:28	123	24.80
7/10/2013	blank	2	A	na	7/10/2013 9:25	7/10/2013 11:28	123	28.58
7/10/2013	blank	2	B	no	7/10/2013 9:25	7/10/2013 11:28	123	25.98

Columns Run Date	Type of Run	BAM #	Column Type	Antibiotic	Start Time	End Time	Exact Flow duration (min)	Mass of Water in Basin (kg)
7/10/2013	blank	2	C	na	7/10/2013 9:25	7/10/2013 11:28	123	25.30
7/10/2013	blank	3	A	na	7/10/2013 9:25	7/10/2013 11:28	123	27.43
7/10/2013	blank	3	B	no	7/10/2013 9:25	7/10/2013 11:28	123	29.22
7/10/2013	blank	3	C	na	7/10/2013 9:25	7/10/2013 11:28	123	27.22
7/11/2013	sample	1	A	na	7/11/2013 11:00	7/12/2013 11:20	1460	46.30
7/11/2013	sample	1	B	no	7/11/2013 11:00	7/12/2013 11:20	1460	29.24
7/11/2013	sample	1	C	na	7/11/2013 11:00	7/12/2013 11:20	1460	27.68
7/11/2013	sample	2	A	na	7/11/2013 11:00	7/12/2013 11:20	1460	30.71
7/11/2013	sample	2	B	no	7/11/2013 11:00	7/12/2013 11:20	1460	36.33
7/11/2013	sample	2	C	na	7/11/2013 11:00	7/12/2013 11:20	1460	27.95
7/11/2013	sample	3	A	na	7/11/2013 11:00	7/12/2013 11:20	1460	35.33
7/11/2013	sample	3	B	no	7/11/2013 11:00	7/12/2013 11:20	1460	37.68
7/11/2013	sample	3	C	na	7/11/2013 11:00	7/12/2013 11:20	1460	35.91
7/16/2013	blank	1	A	na	7/16/2013 16:42	7/16/2013 18:42	120	30.26
7/16/2013	blank	1	B	no	7/16/2013 16:42	7/16/2013 18:42	120	22.16
7/16/2013	blank	1	C	na	7/16/2013 16:42	7/16/2013 18:42	120	26.00
7/16/2013	blank	2	A	na	7/16/2013 16:42	7/16/2013 18:42	120	28.54
7/16/2013	blank	2	B	no	7/16/2013 16:42	7/16/2013 18:42	120	29.08
7/16/2013	blank	2	C	na	7/16/2013 16:42	7/16/2013 18:42	120	25.18
7/16/2013	blank	3	A	na	7/16/2013 16:42	7/16/2013 18:42	120	27.30
7/16/2013	blank	3	B	no	7/16/2013 16:42	7/16/2013 18:42	120	23.58

Columns Run Date	Type of Run	BAM #	Column Type	Antibiotic	Start Time	End Time	Exact Flow duration (min)	Mass of Water in Basin (kg)
7/16/2013	blank	3	C	na	7/16/2013 16:42	7/16/2013 18:42	120	27.60
7/19/2013	blank	1	A	na	7/19/2013 11:25	7/19/2013 13:25	120	32.20
7/19/2013	blank	1	B	no	7/19/2013 11:25	7/19/2013 13:25	120	26.04
7/19/2013	blank	1	C	na	7/19/2013 11:25	7/19/2013 13:25	120	24.92
7/19/2013	blank	2	A	na	7/19/2013 11:25	7/19/2013 13:25	120	26.80
7/19/2013	blank	2	B	no	7/19/2013 11:25	7/19/2013 13:25	120	26.00
7/19/2013	blank	2	C	na	7/19/2013 11:25	7/19/2013 13:25	120	22.16
7/19/2013	blank	3	A	na	7/19/2013 11:25	7/19/2013 13:25	120	27.98
7/19/2013	blank	3	B	no	7/19/2013 11:25	7/19/2013 13:25	120	28.44
7/19/2013	blank	3	C	na	7/19/2013 11:25	7/19/2013 13:25	120	28.42
7/22/2013	blank	1	A	na	7/22/2013 12:06	7/22/2013 14:13	127	32.68
7/22/2013	blank	1	B	no	7/22/2013 12:06	7/22/2013 14:13	127	27.44
7/22/2013	blank	1	C	na	7/22/2013 12:06	7/22/2013 14:13	127	27.64
7/22/2013	blank	2	A	na	7/22/2013 12:06	7/22/2013 14:13	127	29.48
7/22/2013	blank	2	B	no	7/22/2013 12:06	7/22/2013 14:13	127	30.98
7/22/2013	blank	2	C	na	7/22/2013 12:06	7/22/2013 14:13	127	26.96
7/22/2013	blank	3	A	na	7/22/2013 12:06	7/22/2013 14:13	127	29.56
7/22/2013	blank	3	B	no	7/22/2013 12:06	7/22/2013 14:13	127	29.58
7/22/2013	blank	3	C	na	7/22/2013 12:06	7/22/2013 14:13	127	30.52
7/23/2013	blank	1	A	na	7/23/2013 9:56	7/23/2013 12:00	124	29.62
7/23/2013	blank	1	B	no	7/23/2013 9:56	7/23/2013 12:00	124	27.76

Columns Run Date	Type of Run	BAM #	Column Type	Antibiotic	Start Time	End Time	Exact Flow duration (min)	Mass of Water in Basin (kg)
7/23/2013	blank	1	C	na	7/23/2013 9:56	7/23/2013 12:00	124	26.56
7/23/2013	blank	2	A	na	7/23/2013 9:56	7/23/2013 12:00	124	28.40
7/23/2013	blank	2	B	no	7/23/2013 9:56	7/23/2013 12:00	124	29.96
7/23/2013	blank	2	C	na	7/23/2013 9:56	7/23/2013 12:00	124	25.20
7/23/2013	blank	3	A	na	7/23/2013 9:56	7/23/2013 12:00	124	28.74
7/23/2013	blank	3	B	no	7/23/2013 9:56	7/23/2013 12:00	124	28.30
7/23/2013	blank	3	C	na	7/23/2013 9:56	7/23/2013 12:00	124	28.48
7/24/2013	sample	1	A	na	7/24/2013 10:35	7/25/2013 10:35	1440	18.94
7/24/2013	sample	1	B	no	7/24/2013 10:35	7/25/2013 10:35	1440	29.06
7/24/2013	sample	1	C	na	7/24/2013 10:35	7/25/2013 10:35	1440	28.38
7/24/2013	sample	2	A	na	7/24/2013 10:35	7/25/2013 10:35	1440	33.96
7/24/2013	sample	2	B	no	7/24/2013 10:35	7/25/2013 10:35	1440	35.06
7/24/2013	sample	2	C	na	7/24/2013 10:35	7/25/2013 10:35	1440	27.38
7/24/2013	sample	3	A	na	7/24/2013 10:35	7/25/2013 10:35	1440	40.48
7/24/2013	sample	3	B	no	7/24/2013 10:35	7/25/2013 10:35	1440	38.98
7/24/2013	sample	3	C	na	7/24/2013 10:35	7/25/2013 10:35	1440	41.62
7/26/2013	sample	1	A	na	7/26/2013 10:12	7/26/2013 12:14	122	31.02
7/26/2013	sample	1	B	no	7/26/2013 10:12	7/26/2013 12:14	122	27.20
7/26/2013	sample	1	C	na	7/26/2013 10:12	7/26/2013 12:14	122	24.58
7/26/2013	sample	2	A	na	7/26/2013 10:12	7/26/2013 12:14	122	26.24
7/26/2013	sample	2	B	no	7/26/2013 10:12	7/26/2013 12:14	122	27.42

Columns Run Date	Type of Run	BAM #	Column Type	Antibiotic	Start Time	End Time	Exact Flow duration (min)	Mass of Water in Basin (kg)
7/26/2013	sample	2	C	na	7/26/2013 10:12	7/26/2013 12:14	122	20.98
7/26/2013	sample	3	A	na	7/26/2013 10:12	7/26/2013 12:14	122	26.08
7/26/2013	sample	3	B	no	7/26/2013 10:12	7/26/2013 12:14	122	17.96
7/26/2013	sample	3	C	na	7/26/2013 10:12	7/26/2013 12:14	122	25.92
7/29/2013	blank	1	A	na	7/29/2013 16:00	7/29/2013 18:11	131	32.16
7/29/2013	blank	1	B	no	7/29/2013 16:00	7/29/2013 18:11	131	14.86
7/29/2013	blank	1	C	na	7/29/2013 16:00	7/29/2013 18:11	131	25.02
7/29/2013	blank	2	A	na	7/29/2013 16:00	7/29/2013 18:11	131	27.76
7/29/2013	blank	2	B	no	7/29/2013 16:00	7/29/2013 18:11	131	30.42
7/29/2013	blank	2	C	na	7/29/2013 16:00	7/29/2013 18:11	131	36.08
7/29/2013	blank	3	A	na	7/29/2013 16:00	7/29/2013 18:11	131	29.60
7/29/2013	blank	3	B	no	7/29/2013 16:00	7/29/2013 18:11	131	22.42
7/29/2013	blank	3	C	na	7/29/2013 16:00	7/29/2013 18:11	131	26.86
7/30/2013	blank	1	A	na	7/30/2013 11:08	7/30/2013 13:08	120	30.56
7/30/2013	blank	1	B	no	7/30/2013 11:08	7/30/2013 13:08	120	26.26
7/30/2013	blank	1	C	na	7/30/2013 11:08	7/30/2013 13:08	120	24.94
7/30/2013	blank	2	A	na	7/30/2013 11:08	7/30/2013 13:08	120	26.94
7/30/2013	blank	2	B	no	7/30/2013 11:08	7/30/2013 13:08	120	29.26
7/30/2013	blank	2	C	na	7/30/2013 11:08	7/30/2013 13:08	120	29.72
7/30/2013	blank	3	A	na	7/30/2013 11:08	7/30/2013 13:08	120	24.54
7/30/2013	blank	3	B	no	7/30/2013 11:08	7/30/2013 13:08	120	23.86

Columns Run Date	Type of Run	BAM #	Column Type	Antibiotic	Start Time	End Time	Exact Flow duration (min)	Mass of Water in Basin (kg)
7/30/2013	blank	3	C	na	7/30/2013 11:08	7/30/2013 13:08	120	24.64
7/31/2013	sample	1	A	na	7/31/2013 7:30	7/31/2013 9:30	120	30.08
7/31/2013	sample	1	B	no	7/31/2013 7:30	7/31/2013 9:30	120	26.30
7/31/2013	sample	1	C	na	7/31/2013 7:30	7/31/2013 9:30	120	24.52
7/31/2013	sample	2	A	na	7/31/2013 7:30	7/31/2013 9:30	120	27.82
7/31/2013	sample	2	B	no	7/31/2013 7:30	7/31/2013 9:30	120	29.06
7/31/2013	sample	2	C	na	7/31/2013 7:30	7/31/2013 9:30	120	29.54
7/31/2013	sample	3	A	na	7/31/2013 7:30	7/31/2013 9:30	120	25.38
7/31/2013	sample	3	B	no	7/31/2013 7:30	7/31/2013 9:30	120	24.92
7/31/2013	sample	3	C	na	7/31/2013 7:30	7/31/2013 9:30	120	28.82
8/1/2013	sample	1	A	na	8/1/2013 11:45	8/2/2013 11:45	1440	32.82
8/1/2013	sample	1	B	no	8/1/2013 11:45	8/2/2013 11:45	1440	24.38
8/1/2013	sample	1	C	na	8/1/2013 11:45	8/2/2013 11:45	1440	25.58
8/1/2013	sample	2	A	na	8/1/2013 11:45	8/2/2013 11:45	1440	30.78
8/1/2013	sample	2	B	no	8/1/2013 11:45	8/2/2013 11:45	1440	31.70
8/1/2013	sample	2	C	na	8/1/2013 11:45	8/2/2013 11:45	1440	30.96
8/1/2013	sample	3	A	na	8/1/2013 11:45	8/2/2013 11:45	1440	39.76
8/1/2013	sample	3	B	no	8/1/2013 11:45	8/2/2013 11:45	1440	47.74
8/1/2013	sample	3	C	na	8/1/2013 11:45	8/2/2013 11:45	1440	39.28
8/5/2013	sample	1	A	na	8/5/2013 9:30	8/6/2013 9:30	1440	20.96
8/5/2013	sample	1	B	no	8/5/2013 9:30	8/6/2013 9:30	1440	24.20

Columns Run Date	Type of Run	BAM #	Column Type	Antibiotic	Start Time	End Time	Exact Flow duration (min)	Mass of Water in Basin (kg)
8/5/2013	sample	1	C	na	8/5/2013 9:30	8/6/2013 9:30	1440	25.16
8/5/2013	sample	2	A	na	8/5/2013 9:30	8/6/2013 9:30	1440	27.86
8/5/2013	sample	2	B	no	8/5/2013 9:30	8/6/2013 9:30	1440	28.08
8/5/2013	sample	2	C	na	8/5/2013 9:30	8/6/2013 9:30	1440	28.32
8/5/2013	sample	3	A	na	8/5/2013 9:30	8/6/2013 9:30	1440	27.48
8/5/2013	sample	3	B	no	8/5/2013 9:30	8/6/2013 9:30	1440	34.34
8/5/2013	sample	3	C	na	8/5/2013 9:30	8/6/2013 9:30	1440	28.34
8/7/2013	sample	1	A	na	8/7/2013 7:30	8/7/2013 9:30	120	29.76
8/7/2013	sample	1	B	no	8/7/2013 7:30	8/7/2013 9:30	120	24.34
8/7/2013	sample	1	C	na	8/7/2013 7:30	8/7/2013 9:30	120	25.22
8/7/2013	sample	2	A	na	8/7/2013 7:30	8/7/2013 9:30	120	27.08
8/7/2013	sample	2	B	no	8/7/2013 7:30	8/7/2013 9:30	120	19.16
8/7/2013	sample	2	C	na	8/7/2013 7:30	8/7/2013 9:30	120	26.34
8/7/2013	sample	3	A	na	8/7/2013 7:30	8/7/2013 9:30	120	21.80
8/7/2013	sample	3	B	no	8/7/2013 7:30	8/7/2013 9:30	120	29.70
8/7/2013	sample	3	C	na	8/7/2013 7:30	8/7/2013 9:30	120	22.98
8/8/2013	blank	1	A	na	8/8/2013 7:30	8/8/2013 9:30	120	29.86
8/8/2013	blank	1	B	no	8/8/2013 7:30	8/8/2013 9:30	120	24.12
8/8/2013	blank	1	C	na	8/8/2013 7:30	8/8/2013 9:30	120	25.02
8/8/2013	blank	2	A	na	8/8/2013 7:30	8/8/2013 9:30	120	27.02
8/8/2013	blank	2	B	no	8/8/2013 7:30	8/8/2013 9:30	120	9.74

Columns Run Date	Type of Run	BAM #	Column Type	Antibiotic	Start Time	End Time	Exact Flow duration (min)	Mass of Water in Basin (kg)
8/8/2013	blank	2	C	na	8/8/2013 7:30	8/8/2013 9:30	120	26.54
8/8/2013	blank	3	A	na	8/8/2013 7:30	8/8/2013 9:30	120	21.82
8/8/2013	blank	3	B	no	8/8/2013 7:30	8/8/2013 9:30	120	22.94
8/8/2013	blank	3	C	na	8/8/2013 7:30	8/8/2013 9:30	120	29.60
8/9/2013	blank	1	A	na	8/9/2013 7:30	8/9/2013 9:30	120	29.74
8/9/2013	blank	1	B	no	8/9/2013 7:30	8/9/2013 9:30	120	23.88
8/9/2013	blank	1	C	na	8/9/2013 7:30	8/9/2013 9:30	120	24.78
8/9/2013	blank	2	A	na	8/9/2013 7:30	8/9/2013 9:30	120	27.48
8/9/2013	blank	2	B	no	8/9/2013 7:30	8/9/2013 9:30	120	na
8/9/2013	blank	2	C	na	8/9/2013 7:30	8/9/2013 9:30	120	37.10
8/9/2013	blank	3	A	na	8/9/2013 7:30	8/9/2013 9:30	120	22.68
8/9/2013	blank	3	B	no	8/9/2013 7:30	8/9/2013 9:30	120	29.30
8/9/2013	blank	3	C	na	8/9/2013 7:30	8/9/2013 9:30	120	22.74
8/12/2013	blank	1	A	na	8/12/2013 7:30	8/12/2013 9:30	120	30.08
8/12/2013	blank	1	B	no	8/12/2013 7:30	8/12/2013 9:30	120	23.96
8/12/2013	blank	1	C	na	8/12/2013 7:30	8/12/2013 9:30	120	24.72
8/12/2013	blank	2	A	na	8/12/2013 7:30	8/12/2013 9:30	120	28.76
8/12/2013	blank	2	B	no	8/12/2013 7:30	8/12/2013 9:30	120	13.51
8/12/2013	blank	2	C	na	8/12/2013 7:30	8/12/2013 9:30	120	26.98
8/12/2013	blank	3	A	na	8/12/2013 7:30	8/12/2013 9:30	120	22.72
8/12/2013	blank	3	B	no	8/12/2013 7:30	8/12/2013 9:30	120	29.42

Columns Run Date	Type of Run	BAM #	Column Type	Antibiotic	Start Time	End Time	Exact Flow duration (min)	Mass of Water in Basin (kg)
8/12/2013	blank	3	C	na	8/12/2013 7:30	8/12/2013 9:30	120	23.10
8/13/2013	sample	1	A	na	8/13/2013 9:30	8/14/2013 9:30	1440	27.90
8/13/2013	sample	1	B	no	8/13/2013 9:30	8/14/2013 9:30	1440	31.16
8/13/2013	sample	1	C	na	8/13/2013 9:30	8/14/2013 9:30	1440	31.70
8/13/2013	sample	2	A	na	8/13/2013 9:30	8/14/2013 9:30	1440	33.28
8/13/2013	sample	2	B	no	8/13/2013 9:30	8/14/2013 9:30	1440	32.90
8/13/2013	sample	2	C	na	8/13/2013 9:30	8/14/2013 9:30	1440	32.37
8/13/2013	sample	3	A	na	8/13/2013 9:30	8/14/2013 9:30	1440	33.90
8/13/2013	sample	3	B	no	8/13/2013 9:30	8/14/2013 9:30	1440	34.06
8/13/2013	sample	3	C	na	8/13/2013 9:30	8/14/2013 9:30	1440	31.56
8/15/2013	sample	1	A	na	8/15/2013 11:05	8/15/2013 13:05	120	30.92
8/15/2013	sample	1	B	no	8/15/2013 11:05	8/15/2013 13:05	120	24.52
8/15/2013	sample	1	C	na	8/15/2013 11:05	8/15/2013 13:05	120	25.24
8/15/2013	sample	2	A	na	8/15/2013 11:05	8/15/2013 13:05	120	26.80
8/15/2013	sample	2	B	no	8/15/2013 11:05	8/15/2013 13:05	120	26.18
8/15/2013	sample	2	C	na	8/15/2013 11:05	8/15/2013 13:05	120	26.02
8/15/2013	sample	3	A	na	8/15/2013 11:05	8/15/2013 13:05	120	26.96
8/15/2013	sample	3	B	no	8/15/2013 11:05	8/15/2013 13:05	120	27.46
8/15/2013	sample	3	C	na	8/15/2013 11:05	8/15/2013 13:05	120	25.28
8/16/2013	blank	1	A	na	8/16/2013 11:05	8/16/2013 13:08	123	31.06
8/16/2013	blank	1	B	no	8/16/2013 11:05	8/16/2013 13:08	123	25.18

Columns Run Date	Type of Run	BAM #	Column Type	Antibiotic	Start Time	End Time	Exact Flow duration (min)	Mass of Water in Basin (kg)
8/16/2013	blank	1	C	na	8/16/2013 11:05	8/16/2013 13:08	123	25.68
8/16/2013	blank	2	A	na	8/16/2013 11:05	8/16/2013 13:08	123	27.28
8/16/2013	blank	2	B	no	8/16/2013 11:05	8/16/2013 13:08	123	26.42
8/16/2013	blank	2	C	na	8/16/2013 11:05	8/16/2013 13:08	123	26.17
8/16/2013	blank	3	A	na	8/16/2013 11:05	8/16/2013 13:08	123	27.49
8/16/2013	blank	3	B	no	8/16/2013 11:05	8/16/2013 13:08	123	27.74
8/16/2013	blank	3	C	na	8/16/2013 11:05	8/16/2013 13:08	123	25.78
8/23/2013	blank	1	A	na	8/23/2013 7:30	8/23/2013 9:30	120	31.56
8/23/2013	blank	1	B	no	8/23/2013 7:30	8/23/2013 9:30	120	23.96
8/23/2013	blank	1	C	na	8/23/2013 7:30	8/23/2013 9:30	120	24.50
8/23/2013	blank	2	A	na	8/23/2013 7:30	8/23/2013 9:30	120	30.34
8/23/2013	blank	2	B	no	8/23/2013 7:30	8/23/2013 9:30	120	25.14
8/23/2013	blank	2	C	na	8/23/2013 7:30	8/23/2013 9:30	120	25.26
8/23/2013	blank	3	A	na	8/23/2013 7:30	8/23/2013 9:30	120	26.52
8/23/2013	blank	3	B	no	8/23/2013 7:30	8/23/2013 9:30	120	27.50
8/23/2013	blank	3	C	na	8/23/2013 7:30	8/23/2013 9:30	120	24.42
8/26/2013	blank	1	A	na	8/26/2013 7:00	8/26/2013 9:00	120	30.20
8/26/2013	blank	1	B	no	8/26/2013 7:00	8/26/2013 9:00	120	24.02
8/26/2013	blank	1	C	na	8/26/2013 7:00	8/26/2013 9:00	120	24.61
8/26/2013	blank	2	A	na	8/26/2013 7:00	8/26/2013 9:00	120	29.98
8/26/2013	blank	2	B	no	8/26/2013 7:00	8/26/2013 9:00	120	15.58

Columns Run Date	Type of Run	BAM #	Column Type	Antibiotic	Start Time	End Time	Exact Flow duration (min)	Mass of Water in Basin (kg)
8/26/2013	blank	2	C	na	8/26/2013 7:00	8/26/2013 9:00	120	30.88
8/26/2013	blank	3	A	na	8/26/2013 7:00	8/26/2013 9:00	120	26.88
8/26/2013	blank	3	B	no	8/26/2013 7:00	8/26/2013 9:00	120	27.61
8/26/2013	blank	3	C	na	8/26/2013 7:00	8/26/2013 9:00	120	24.84
8/27/2013	sample	1	A	na	8/27/2013 9:00	8/28/2013 9:00	1440	23.36
8/27/2013	sample	1	B	no	8/27/2013 9:00	8/28/2013 9:00	1440	30.50
8/27/2013	sample	1	C	na	8/27/2013 9:00	8/28/2013 9:00	1440	30.94
8/27/2013	sample	2	A	na	8/27/2013 9:00	8/28/2013 9:00	1440	22.12
8/27/2013	sample	2	B	no	8/27/2013 9:00	8/28/2013 9:00	1440	22.48
8/27/2013	sample	2	C	na	8/27/2013 9:00	8/28/2013 9:00	1440	20.60
8/27/2013	sample	3	A	na	8/27/2013 9:00	8/28/2013 9:00	1440	40.72
8/27/2013	sample	3	B	no	8/27/2013 9:00	8/28/2013 9:00	1440	40.62
8/27/2013	sample	3	C	na	8/27/2013 9:00	8/28/2013 9:00	1440	38.14
8/29/2013	blank	1	A	na	8/29/2013 12:15	8/29/2013 14:15	120	30.82
8/29/2013	blank	1	B	no	8/29/2013 12:15	8/29/2013 14:15	120	23.92
8/29/2013	blank	1	C	na	8/29/2013 12:15	8/29/2013 14:15	120	24.46
8/29/2013	blank	2	A	na	8/29/2013 12:15	8/29/2013 14:15	120	26.18
8/29/2013	blank	2	B	no	8/29/2013 12:15	8/29/2013 14:15	120	26.86
8/29/2013	blank	2	C	na	8/29/2013 12:15	8/29/2013 14:15	120	25.44
8/29/2013	blank	3	A	na	8/29/2013 12:15	8/29/2013 14:15	120	26.44
8/29/2013	blank	3	B	no	8/29/2013 12:15	8/29/2013 14:15	120	26.98

Columns Run Date	Type of Run	BAM #	Column Type	Antibiotic	Start Time	End Time	Exact Flow duration (min)	Mass of Water in Basin (kg)
8/29/2013	blank	3	C	na	8/29/2013 12:15	8/29/2013 14:15	120	24.60
8/30/2013	sample	1	A	na	8/30/2013 7:00	8/30/2013 9:00	120	29.12
8/30/2013	sample	1	B	no	8/30/2013 7:00	8/30/2013 9:00	120	24.01
8/30/2013	sample	1	C	na	8/30/2013 7:00	8/30/2013 9:00	120	24.84
8/30/2013	sample	2	A	na	8/30/2013 7:00	8/30/2013 9:00	120	27.92
8/30/2013	sample	2	B	no	8/30/2013 7:00	8/30/2013 9:00	120	28.12
8/30/2013	sample	2	C	na	8/30/2013 7:00	8/30/2013 9:00	120	26.20
8/30/2013	sample	3	A	na	8/30/2013 7:00	8/30/2013 9:00	120	26.25
8/30/2013	sample	3	B	no	8/30/2013 7:00	8/30/2013 9:00	120	na
8/30/2013	sample	3	C	na	8/30/2013 7:00	8/30/2013 9:00	120	24.18
9/3/2013	sample	1	A	na	9/3/2013 9:00	9/4/2013 9:00	1440	30.76
9/3/2013	sample	1	B	no	9/3/2013 9:00	9/4/2013 9:00	1440	27.50
9/3/2013	sample	1	C	na	9/3/2013 9:00	9/4/2013 9:00	1440	28.12
9/3/2013	sample	2	A	na	9/3/2013 9:00	9/4/2013 9:00	1440	32.22
9/3/2013	sample	2	B	no	9/3/2013 9:00	9/4/2013 9:00	1440	32.22
9/3/2013	sample	2	C	na	9/3/2013 9:00	9/4/2013 9:00	1440	31.90
9/3/2013	sample	3	A	na	9/3/2013 9:00	9/4/2013 9:00	1440	34.09
9/3/2013	sample	3	B	no	9/3/2013 9:00	9/4/2013 9:00	1440	32.68
9/3/2013	sample	3	C	na	9/3/2013 9:00	9/4/2013 9:00	1440	31.36
9/24/2013	sample	1	A	na	9/24/2013 9:29	9/25/2013 9:00	1411	19.70
9/24/2013	sample	1	B	no	9/24/2013 9:29	9/25/2013 9:00	1411	32.66

Columns Run Date	Type of Run	BAM #	Column Type	Antibiotic	Start Time	End Time	Exact Flow duration (min)	Mass of Water in Basin (kg)
9/24/2013	sample	1	C	na	9/24/2013 9:29	9/25/2013 9:00	1411	41.18
9/24/2013	sample	2	A	na	9/24/2013 9:29	9/25/2013 9:00	1411	27.70
9/24/2013	sample	2	B	no	9/24/2013 9:29	9/25/2013 9:00	1411	28.36
9/24/2013	sample	2	C	na	9/24/2013 9:29	9/25/2013 9:00	1411	26.66
9/24/2013	sample	3	A	na	9/24/2013 9:29	9/25/2013 9:00	1411	38.66
9/24/2013	sample	3	B	no	9/24/2013 9:29	9/25/2013 9:00	1411	38.42
9/24/2013	sample	3	C	na	9/24/2013 9:29	9/25/2013 9:00	1411	35.92
9/26/2013	blank	1	A	na	9/26/2013 12:52	9/26/2013 14:52	120	30.56
9/26/2013	blank	1	B	no	9/26/2013 12:52	9/26/2013 14:52	120	30.08
9/26/2013	blank	1	C	na	9/26/2013 12:52	9/26/2013 14:52	120	28.70
9/26/2013	blank	2	A	na	9/26/2013 12:52	9/26/2013 14:52	120	28.57
9/26/2013	blank	2	B	no	9/26/2013 12:52	9/26/2013 14:52	120	28.76
9/26/2013	blank	2	C	na	9/26/2013 12:52	9/26/2013 14:52	120	26.46
9/26/2013	blank	3	A	na	9/26/2013 12:52	9/26/2013 14:52	120	27.26
9/26/2013	blank	3	B	no	9/26/2013 12:52	9/26/2013 14:52	120	27.68
9/26/2013	blank	3	C	na	9/26/2013 12:52	9/26/2013 14:52	120	25.21
9/27/2013	sample	1	A	na	9/27/2013 7:00	9/27/2013 9:00	120	28.96
9/27/2013	sample	1	B	no	9/27/2013 7:00	9/27/2013 9:00	120	29.80
9/27/2013	sample	1	C	na	9/27/2013 7:00	9/27/2013 9:00	120	28.34
9/27/2013	sample	2	A	na	9/27/2013 7:00	9/27/2013 9:00	120	27.92
9/27/2013	sample	2	B	no	9/27/2013 7:00	9/27/2013 9:00	120	28.10

Columns Run Date	Type of Run	BAM #	Column Type	Antibiotic	Start Time	End Time	Exact Flow duration (min)	Mass of Water in Basin (kg)
9/27/2013	sample	2	C	na	9/27/2013 7:00	9/27/2013 9:00	120	26.22
9/27/2013	sample	3	A	na	9/27/2013 7:00	9/27/2013 9:00	120	27.16
9/27/2013	sample	3	B	no	9/27/2013 7:00	9/27/2013 9:00	120	27.94
9/27/2013	sample	3	C	na	9/27/2013 7:00	9/27/2013 9:00	120	24.96
9/30/2013	blank	1	A	na	9/30/2013 7:00	9/30/2013 9:00	120	28.36
9/30/2013	blank	1	B	no	9/30/2013 7:00	9/30/2013 9:00	120	29.38
9/30/2013	blank	1	C	na	9/30/2013 7:00	9/30/2013 9:00	120	27.14
9/30/2013	blank	2	A	na	9/30/2013 7:00	9/30/2013 9:00	120	28.90
9/30/2013	blank	2	B	no	9/30/2013 7:00	9/30/2013 9:00	120	29.30
9/30/2013	blank	2	C	na	9/30/2013 7:00	9/30/2013 9:00	120	26.76
9/30/2013	blank	3	A	na	9/30/2013 7:00	9/30/2013 9:00	120	26.98
9/30/2013	blank	3	B	no	9/30/2013 7:00	9/30/2013 9:00	120	27.88
9/30/2013	blank	3	C	na	9/30/2013 7:00	9/30/2013 9:00	120	24.92
10/1/2013	sample	1	A	na	10/1/2013 9:00	10/2/2013 9:00	1440	23.02
10/1/2013	sample	1	B	no	10/1/2013 9:00	10/2/2013 9:00	1440	38.24
10/1/2013	sample	1	C	na	10/1/2013 9:00	10/2/2013 9:00	1440	35.72
10/1/2013	sample	2	A	na	10/1/2013 9:00	10/2/2013 9:00	1440	22.76
10/1/2013	sample	2	B	no	10/1/2013 9:00	10/2/2013 9:00	1440	20.56
10/1/2013	sample	2	C	na	10/1/2013 9:00	10/2/2013 9:00	1440	11.28
10/1/2013	sample	3	A	na	10/1/2013 9:00	10/2/2013 9:00	1440	38.36
10/1/2013	sample	3	B	no	10/1/2013 9:00	10/2/2013 9:00	1440	36.72

Columns Run Date	Type of Run	BAM #	Column Type	Antibiotic	Start Time	End Time	Exact Flow duration (min)	Mass of Water in Basin (kg)
10/1/2013	sample	3	C	na	10/1/2013 9:00	10/2/2013 9:00	1440	33.38
10/3/2013	blank	1	A	na	10/3/2013 13:41	10/3/2013 17:05	204	39.38
10/3/2013	blank	1	B	no	10/3/2013 13:41	10/3/2013 17:05	204	38.70
10/3/2013	blank	1	C	na	10/3/2013 13:41	10/3/2013 17:05	204	39.78
10/3/2013	blank	2	A	na	10/3/2013 13:41	10/3/2013 17:05	204	38.78
10/3/2013	blank	2	B	no	10/3/2013 13:41	10/3/2013 17:05	204	35.78
10/3/2013	blank	2	C	na	10/3/2013 13:41	10/3/2013 17:05	204	41.38
10/3/2013	blank	3	A	na	10/3/2013 13:41	10/3/2013 17:05	204	38.38
10/3/2013	blank	3	B	no	10/3/2013 13:41	10/3/2013 17:05	204	34.86
10/3/2013	blank	3	C	na	10/3/2013 13:41	10/3/2013 17:05	204	35.58
10/4/2013	sample	1	A	na	10/4/2013 7:00	10/4/2013 9:00	120	29.94
10/4/2013	sample	1	B	no	10/4/2013 7:00	10/4/2013 9:00	120	29.04
10/4/2013	sample	1	C	na	10/4/2013 7:00	10/4/2013 9:00	120	27.86
10/4/2013	sample	2	A	na	10/4/2013 7:00	10/4/2013 9:00	120	28.08
10/4/2013	sample	2	B	no	10/4/2013 7:00	10/4/2013 9:00	120	25.36
10/4/2013	sample	2	C	na	10/4/2013 7:00	10/4/2013 9:00	120	27.80
10/4/2013	sample	3	A	na	10/4/2013 7:00	10/4/2013 9:00	120	26.54
10/4/2013	sample	3	B	no	10/4/2013 7:00	10/4/2013 9:00	120	27.50
10/4/2013	sample	3	C	na	10/4/2013 7:00	10/4/2013 9:00	120	21.20
10/7/2013	blank	1	A	na	10/7/2013 7:00	10/7/2013 9:00	120	30.12
10/7/2013	blank	1	B	no	10/7/2013 7:00	10/7/2013 9:00	120	29.26

Columns Run Date	Type of Run	BAM #	Column Type	Antibiotic	Start Time	End Time	Exact Flow duration (min)	Mass of Water in Basin (kg)
10/7/2013	blank	1	C	na	10/7/2013 7:00	10/7/2013 9:00	120	27.96
10/7/2013	blank	2	A	na	10/7/2013 7:00	10/7/2013 9:00	120	28.96
10/7/2013	blank	2	B	no	10/7/2013 7:00	10/7/2013 9:00	120	25.40
10/7/2013	blank	2	C	na	10/7/2013 7:00	10/7/2013 9:00	120	28.04
10/7/2013	blank	3	A	na	10/7/2013 7:00	10/7/2013 9:00	120	26.36
10/7/2013	blank	3	B	no	10/7/2013 7:00	10/7/2013 9:00	120	27.48
10/7/2013	blank	3	C	na	10/7/2013 7:00	10/7/2013 9:00	120	15.28
10/8/2013	sample	1	A	na	10/8/2013 13:15	10/9/2013 13:15	1440	14.24
10/8/2013	sample	1	B	no	10/8/2013 13:15	10/9/2013 13:15	1440	41.84
10/8/2013	sample	1	C	na	10/8/2013 13:15	10/9/2013 13:15	1440	39.94
10/8/2013	sample	2	A	na	10/8/2013 13:15	10/9/2013 13:15	1440	27.76
10/8/2013	sample	2	B	no	10/8/2013 13:15	10/9/2013 13:15	1440	24.52
10/8/2013	sample	2	C	na	10/8/2013 13:15	10/9/2013 13:15	1440	27.48
10/8/2013	sample	3	A	na	10/8/2013 13:15	10/9/2013 13:15	1440	31.36
10/8/2013	sample	3	B	no	10/8/2013 13:15	10/9/2013 13:15	1440	31.66
10/8/2013	sample	3	C	na	10/8/2013 13:15	10/9/2013 13:15	1440	30.92
10/10/2013	blank	1	A	na	10/10/2013 7:30	10/10/2013 9:30	120	na
10/10/2013	blank	1	B	no	10/10/2013 7:30	10/10/2013 9:30	120	29.12
10/10/2013	blank	1	C	na	10/10/2013 7:30	10/10/2013 9:30	120	27.76
10/10/2013	blank	2	A	na	10/10/2013 7:30	10/10/2013 9:30	120	28.20
10/10/2013	blank	2	B	no	10/10/2013 7:30	10/10/2013 9:30	120	24.38

Columns Run Date	Type of Run	BAM #	Column Type	Antibiotic	Start Time	End Time	Exact Flow duration (min)	Mass of Water in Basin (kg)
10/10/2013	blank	2	C	na	10/10/2013 7:30	10/10/2013 9:30	120	27.12
10/10/2013	blank	3	A	na	10/10/2013 7:30	10/10/2013 9:30	120	27.58
10/10/2013	blank	3	B	no	10/10/2013 7:30	10/10/2013 9:30	120	27.00
10/10/2013	blank	3	C	na	10/10/2013 7:30	10/10/2013 9:30	120	26.32
10/11/2013	blank	1	A	na	10/11/2013 7:00	10/11/2013 9:00	120	26.02
10/11/2013	blank	1	B	no	10/11/2013 7:00	10/11/2013 9:00	120	24.30
10/11/2013	blank	1	C	na	10/11/2013 7:00	10/11/2013 9:00	120	28.00
10/11/2013	blank	2	A	na	10/11/2013 7:00	10/11/2013 9:00	120	24.86
10/11/2013	blank	2	B	no	10/11/2013 7:00	10/11/2013 9:00	120	0.84
10/11/2013	blank	2	C	na	10/11/2013 7:00	10/11/2013 9:00	120	27.28
10/11/2013	blank	3	A	na	10/11/2013 7:00	10/11/2013 9:00	120	27.46
10/11/2013	blank	3	B	no	10/11/2013 7:00	10/11/2013 9:00	120	22.74
10/11/2013	blank	3	C	na	10/11/2013 7:00	10/11/2013 9:00	120	26.24
10/14/2013	blank	1	A	na	10/14/2013 7:00	10/14/2013 9:00	120	29.50
10/14/2013	blank	1	B	no	10/14/2013 7:00	10/14/2013 9:00	120	28.08
10/14/2013	blank	1	C	na	10/14/2013 7:00	10/14/2013 9:00	120	19.46
10/14/2013	blank	2	A	na	10/14/2013 7:00	10/14/2013 9:00	120	29.42
10/14/2013	blank	2	B	no	10/14/2013 7:00	10/14/2013 9:00	120	na
10/14/2013	blank	2	C	na	10/14/2013 7:00	10/14/2013 9:00	120	28.54
10/14/2013	blank	3	A	na	10/14/2013 7:00	10/14/2013 9:00	120	29.92
10/14/2013	blank	3	B	no	10/14/2013 7:00	10/14/2013 9:00	120	28.70

Columns Run Date	Type of Run	BAM #	Column Type	Antibiotic	Start Time	End Time	Exact Flow duration (min)	Mass of Water in Basin (kg)
10/14/2013	blank	3	C	na	10/14/2013 7:00	10/14/2013 9:00	120	29.18
10/15/2013	sample	1	A	na	10/15/2013 9:00	10/16/2013 9:00	1440	35.52
10/15/2013	sample	1	B	no	10/15/2013 9:00	10/16/2013 9:00	1440	42.34
10/15/2013	sample	1	C	na	10/15/2013 9:00	10/16/2013 9:00	1440	44.02
10/15/2013	sample	2	A	na	10/15/2013 9:00	10/16/2013 9:00	1440	22.46
10/15/2013	sample	2	B	no	10/15/2013 9:00	10/16/2013 9:00	1440	24.14
10/15/2013	sample	2	C	na	10/15/2013 9:00	10/16/2013 9:00	1440	23.62
10/15/2013	sample	3	A	na	10/15/2013 9:00	10/16/2013 9:00	1440	37.20
10/15/2013	sample	3	B	no	10/15/2013 9:00	10/16/2013 9:00	1440	24.66
10/15/2013	sample	3	C	na	10/15/2013 9:00	10/16/2013 9:00	1440	35.66
10/17/2013	blank	1	A	na	10/17/2013 8:00	10/17/2013 10:00	120	na
10/17/2013	blank	1	B	no	10/17/2013 8:00	10/17/2013 10:00	120	27.08
10/17/2013	blank	1	C	na	10/17/2013 8:00	10/17/2013 10:00	120	28.26
10/17/2013	blank	2	A	na	10/17/2013 8:00	10/17/2013 10:00	120	27.46
10/17/2013	blank	2	B	no	10/17/2013 8:00	10/17/2013 10:00	120	27.34
10/17/2013	blank	2	C	na	10/17/2013 8:00	10/17/2013 10:00	120	27.00
10/17/2013	blank	3	A	na	10/17/2013 8:00	10/17/2013 10:00	120	29.26
10/17/2013	blank	3	B	no	10/17/2013 8:00	10/17/2013 10:00	120	29.16
10/17/2013	blank	3	C	na	10/17/2013 8:00	10/17/2013 10:00	120	28.74
10/18/2013	sample	1	A	na	10/18/2013 7:00	10/18/2013 9:00	120	26.04
10/18/2013	sample	1	B	no	10/18/2013 7:00	10/18/2013 9:00	120	26.98
10/18/2013	sample	1	C	na	10/18/2013 7:00	10/18/2013 9:00	120	38.16

Columns Run Date	Type of Run	BAM #	Column Type	Antibiotic	Start Time	End Time	Exact Flow duration (min)	Mass of Water in Basin (kg)
10/18/2013	sample	2	A	na	10/18/2013 7:00	10/18/2013 9:00	120	27.66
10/18/2013	sample	2	B	no	10/18/2013 7:00	10/18/2013 9:00	120	27.26
10/18/2013	sample	2	C	na	10/18/2013 7:00	10/18/2013 9:00	120	26.98
10/18/2013	sample	3	A	na	10/18/2013 7:00	10/18/2013 9:00	120	29.12
10/18/2013	sample	3	B	no	10/18/2013 7:00	10/18/2013 9:00	120	29.10
10/18/2013	sample	3	C	na	10/18/2013 7:00	10/18/2013 9:00	120	27.94
10/21/2013	blank	1	A	na	10/21/2013 9:55	10/21/2013 11:55	120	23.41
10/21/2013	blank	1	B	no	10/21/2013 9:55	10/21/2013 11:55	120	27.66
10/21/2013	blank	1	C	na	10/21/2013 9:55	10/21/2013 11:55	120	28.86
10/21/2013	blank	2	A	na	10/21/2013 9:55	10/21/2013 11:55	120	27.76
10/21/2013	blank	2	B	no	10/21/2013 9:55	10/21/2013 11:55	120	27.16
10/21/2013	blank	2	C	na	10/21/2013 9:55	10/21/2013 11:55	120	26.46
10/21/2013	blank	3	A	na	10/21/2013 9:55	10/21/2013 11:55	120	29.46
10/21/2013	blank	3	B	no	10/21/2013 9:55	10/21/2013 11:55	120	29.06
10/21/2013	blank	3	C	na	10/21/2013 9:55	10/21/2013 11:55	120	28.26
10/22/2013	sample	1	A	na	10/22/2013 9:00	10/23/2013 9:00	1440	22.76
10/22/2013	sample	1	B	no	10/22/2013 9:00	10/23/2013 9:00	1440	38.78
10/22/2013	sample	1	C	na	10/22/2013 9:00	10/23/2013 9:00	1440	40.30
10/22/2013	sample	2	A	na	10/22/2013 9:00	10/23/2013 9:00	1440	28.22
10/22/2013	sample	2	B	no	10/22/2013 9:00	10/23/2013 9:00	1440	27.74
10/22/2013	sample	2	C	na	10/22/2013 9:00	10/23/2013 9:00	1440	27.68
10/22/2013	sample	3	A	na	10/22/2013 9:00	10/23/2013 9:00	1440	42.08

Columns Run Date	Type of Run	BAM #	Column Type	Antibiotic	Start Time	End Time	Exact Flow duration (min)	Mass of Water in Basin (kg)
10/22/2013	sample	3	B	no	10/22/2013 9:00	10/23/2013 9:00	1440	39.92
10/22/2013	sample	3	C	na	10/22/2013 9:00	10/23/2013 9:00	1440	39.64
10/24/2013	blank	1	A	na	10/24/2013 7:00	10/24/2013 9:00	120	25.34
10/24/2013	blank	1	B	no	10/24/2013 7:00	10/24/2013 9:00	120	27.00
10/24/2013	blank	1	C	na	10/24/2013 7:00	10/24/2013 9:00	120	28.16
10/24/2013	blank	2	A	na	10/24/2013 7:00	10/24/2013 9:00	120	27.44
10/24/2013	blank	2	B	no	10/24/2013 7:00	10/24/2013 9:00	120	26.38
10/24/2013	blank	2	C	na	10/24/2013 7:00	10/24/2013 9:00	120	26.20
10/24/2013	blank	3	A	na	10/24/2013 7:00	10/24/2013 9:00	120	25.84
10/24/2013	blank	3	B	no	10/24/2013 7:00	10/24/2013 9:00	120	29.68
10/24/2013	blank	3	C	na	10/24/2013 7:00	10/24/2013 9:00	120	28.28
10/25/2013	sample	1	A	na	10/25/2013 7:00	10/25/2013 9:00	120	28.28
10/25/2013	sample	1	B	no	10/25/2013 7:00	10/25/2013 9:00	120	28.28
10/25/2013	sample	1	C	na	10/25/2013 7:00	10/25/2013 9:00	120	28.28
10/25/2013	sample	2	A	na	10/25/2013 7:00	10/25/2013 9:00	120	28.28
10/25/2013	sample	2	B	no	10/25/2013 7:00	10/25/2013 9:00	120	28.28
10/25/2013	sample	2	C	na	10/25/2013 7:00	10/25/2013 9:00	120	28.28
10/25/2013	sample	3	A	na	10/25/2013 7:00	10/25/2013 9:00	120	28.28
10/25/2013	sample	3	B	no	10/25/2013 7:00	10/25/2013 9:00	120	28.28
10/25/2013	sample	3	C	na	10/25/2013 7:00	10/25/2013 9:00	120	28.28
10/29/2013	sample	1	A	na	10/29/2013 9:00	10/30/2013 9:00	1440	21.02
10/29/2013	sample	1	B	no	10/29/2013 9:00	10/30/2013 9:00	1440	34.94

Columns Run Date	Type of Run	BAM #	Column Type	Antibiotic	Start Time	End Time	Exact Flow duration (min)	Mass of Water in Basin (kg)
10/29/2013	sample	1	C	na	10/29/2013 9:00	10/30/2013 9:00	1440	36.80
10/29/2013	sample	2	A	na	10/29/2013 9:00	10/30/2013 9:00	1440	26.52
10/29/2013	sample	2	B	no	10/29/2013 9:00	10/30/2013 9:00	1440	25.56
10/29/2013	sample	2	C	na	10/29/2013 9:00	10/30/2013 9:00	1440	25.56
10/29/2013	sample	3	A	na	10/29/2013 9:00	10/30/2013 9:00	1440	35.14
10/29/2013	sample	3	B	no	10/29/2013 9:00	10/30/2013 9:00	1440	38.38
10/29/2013	sample	3	C	na	10/29/2013 9:00	10/30/2013 9:00	1440	36.60
11/1/2013	sample	1	A	na	11/1/2013 7:00	11/1/2013 9:00	120	26.36
11/1/2013	sample	1	B	no	11/1/2013 7:00	11/1/2013 9:00	120	26.90
11/1/2013	sample	1	C	na	11/1/2013 7:00	11/1/2013 9:00	120	28.04
11/1/2013	sample	2	A	na	11/1/2013 7:00	11/1/2013 9:00	120	29.76
11/1/2013	sample	2	B	no	11/1/2013 7:00	11/1/2013 9:00	120	28.41
11/1/2013	sample	2	C	na	11/1/2013 7:00	11/1/2013 9:00	120	28.02
11/1/2013	sample	3	A	na	11/1/2013 7:00	11/1/2013 9:00	120	25.54
11/1/2013	sample	3	B	no	11/1/2013 7:00	11/1/2013 9:00	120	26.32
11/1/2013	sample	3	C	na	11/1/2013 7:00	11/1/2013 9:00	120	29.84
11/4/2013	blank	1	A	na	11/4/2013 7:00	11/4/2013 9:00	120	25.52
11/4/2013	blank	1	B	no	11/4/2013 7:00	11/4/2013 9:00	120	27.60
11/4/2013	blank	1	C	na	11/4/2013 7:00	11/4/2013 9:00	120	27.62
11/4/2013	blank	2	A	na	11/4/2013 7:00	11/4/2013 9:00	120	28.50
11/4/2013	blank	2	B	no	11/4/2013 7:00	11/4/2013 9:00	120	27.16

Columns Run Date	Type of Run	BAM #	Column Type	Antibiotic	Start Time	End Time	Exact Flow duration (min)	Mass of Water in Basin (kg)
11/4/2013	blank	2	C	na	11/4/2013 7:00	11/4/2013 9:00	120	25.92
11/4/2013	blank	3	A	na	11/4/2013 7:00	11/4/2013 9:00	120	25.20
11/4/2013	blank	3	B	no	11/4/2013 7:00	11/4/2013 9:00	120	28.70
11/4/2013	blank	3	C	na	11/4/2013 7:00	11/4/2013 9:00	120	26.44
11/5/2013	sample	1	A	na	11/5/2013 9:00	11/6/2013 9:00	1440	11.64
11/5/2013	sample	1	B	no	11/5/2013 9:00	11/6/2013 9:00	1440	30.76
11/5/2013	sample	1	C	na	11/5/2013 9:00	11/6/2013 9:00	1440	30.90
11/5/2013	sample	2	A	na	11/5/2013 9:00	11/6/2013 9:00	1440	22.10
11/5/2013	sample	2	B	no	11/5/2013 9:00	11/6/2013 9:00	1440	21.54
11/5/2013	sample	2	C	na	11/5/2013 9:00	11/6/2013 9:00	1440	21.76
11/5/2013	sample	3	A	na	11/5/2013 9:00	11/6/2013 9:00	1440	24.54
11/5/2013	sample	3	B	no	11/5/2013 9:00	11/6/2013 9:00	1440	24.76
11/5/2013	sample	3	C	na	11/5/2013 9:00	11/6/2013 9:00	1440	25.62
11/7/2013	blank	1	A	na	11/7/2013 8:30	11/7/2013 10:30	120	24.74
11/7/2013	blank	1	B	no	11/7/2013 8:30	11/7/2013 10:30	120	27.12
11/7/2013	blank	1	C	na	11/7/2013 8:30	11/7/2013 10:30	120	27.42
11/7/2013	blank	2	A	na	11/7/2013 8:30	11/7/2013 10:30	120	28.08
11/7/2013	blank	2	B	no	11/7/2013 8:30	11/7/2013 10:30	120	26.54
11/7/2013	blank	2	C	na	11/7/2013 8:30	11/7/2013 10:30	120	26.28
11/7/2013	blank	3	A	na	11/7/2013 8:30	11/7/2013 10:30	120	24.98
11/7/2013	blank	3	B	no	11/7/2013 8:30	11/7/2013 10:30	120	29.04

Columns Run Date	Type of Run	BAM #	Column Type	Antibiotic	Start Time	End Time	Exact Flow duration (min)	Mass of Water in Basin (kg)
11/7/2013	blank	3	C	na	11/7/2013 8:30	11/7/2013 10:30	120	26.78
11/8/2013	sample	1	A	na	11/8/2013 7:00	11/8/2013 9:00	120	24.58
11/8/2013	sample	1	B	no	11/8/2013 7:00	11/8/2013 9:00	120	27.20
11/8/2013	sample	1	C	na	11/8/2013 7:00	11/8/2013 9:00	120	27.36
11/8/2013	sample	2	A	na	11/8/2013 7:00	11/8/2013 9:00	120	28.32
11/8/2013	sample	2	B	no	11/8/2013 7:00	11/8/2013 9:00	120	26.70
11/8/2013	sample	2	C	na	11/8/2013 7:00	11/8/2013 9:00	120	26.46
11/8/2013	sample	3	A	na	11/8/2013 7:00	11/8/2013 9:00	120	24.88
11/8/2013	sample	3	B	no	11/8/2013 7:00	11/8/2013 9:00	120	28.96
11/8/2013	sample	3	C	na	11/8/2013 7:00	11/8/2013 9:00	120	26.72
11/12/2013	sample	1	A	na	11/12/2013 9:00	11/13/2013 9:00	1440	37.00
11/12/2013	sample	1	B	no	11/12/2013 9:00	11/13/2013 9:00	1440	46.64
11/12/2013	sample	1	C	na	11/12/2013 9:00	11/13/2013 9:00	1440	47.36
11/12/2013	sample	2	A	na	11/12/2013 9:00	11/13/2013 9:00	1440	31.78
11/12/2013	sample	2	B	no	11/12/2013 9:00	11/13/2013 9:00	1440	32.32
11/12/2013	sample	2	C	na	11/12/2013 9:00	11/13/2013 9:00	1440	32.48
11/12/2013	sample	3	A	na	11/12/2013 9:00	11/13/2013 9:00	1440	40.04
11/12/2013	sample	3	B	no	11/12/2013 9:00	11/13/2013 9:00	1440	43.58
11/12/2013	sample	3	C	na	11/12/2013 9:00	11/13/2013 9:00	1440	43.54
11/14/2013	blank	1	A	na	11/14/2013 8:30	11/14/2013 10:30	120	29.02
11/14/2013	blank	1	B	no	11/14/2013 8:30	11/14/2013 10:30	120	30.68
11/14/2013	blank	1	C	na	11/14/2013 8:30	11/14/2013 10:30	120	30.98

Columns Run Date	Type of Run	BAM #	Column Type	Antibiotic	Start Time	End Time	Exact Flow duration (min)	Mass of Water in Basin (kg)
11/14/2013	blank	2	A	na	11/14/2013 8:30	11/14/2013 10:30	120	28.29
11/14/2013	blank	2	B	no	11/14/2013 8:30	11/14/2013 10:30	120	27.08
11/14/2013	blank	2	C	na	11/14/2013 8:30	11/14/2013 10:30	120	30.74
11/14/2013	blank	3	A	na	11/14/2013 8:30	11/14/2013 10:30	120	29.86
11/14/2013	blank	3	B	no	11/14/2013 8:30	11/14/2013 10:30	120	34.42
11/14/2013	blank	3	C	na	11/14/2013 8:30	11/14/2013 10:30	120	30.14
11/15/2013	sample	1	A	na	11/15/2013 7:00	11/15/2013 9:00	120	25.76
11/15/2013	sample	1	B	no	11/15/2013 7:00	11/15/2013 9:00	120	na
11/15/2013	sample	1	C	na	11/15/2013 7:00	11/15/2013 9:00	120	27.74
11/15/2013	sample	2	A	na	11/15/2013 7:00	11/15/2013 9:00	120	28.84
11/15/2013	sample	2	B	no	11/15/2013 7:00	11/15/2013 9:00	120	28.56
11/15/2013	sample	2	C	na	11/15/2013 7:00	11/15/2013 9:00	120	27.52
11/15/2013	sample	3	A	na	11/15/2013 7:00	11/15/2013 9:00	120	26.46
11/15/2013	sample	3	B	no	11/15/2013 7:00	11/15/2013 9:00	120	29.86
11/15/2013	sample	3	C	na	11/15/2013 7:00	11/15/2013 9:00	120	27.08
11/18/2013	blank	1	A	na	11/18/2013 10:30	11/18/2013 12:30	120	27.22
11/18/2013	blank	1	B	no	11/18/2013 10:30	11/18/2013 12:30	120	26.72
11/18/2013	blank	1	C	na	11/18/2013 10:30	11/18/2013 12:30	120	24.64
11/18/2013	blank	2	A	na	11/18/2013 10:30	11/18/2013 12:30	120	24.52
11/18/2013	blank	2	B	no	11/18/2013 10:30	11/18/2013 12:30	120	28.72
11/18/2013	blank	2	C	na	11/18/2013 10:30	11/18/2013 12:30	120	26.32
11/18/2013	blank	3	A	na	11/18/2013 10:30	11/18/2013 12:30	120	23.10

Columns Run Date	Type of Run	BAM #	Column Type	Antibiotic	Start Time	End Time	Exact Flow duration (min)	Mass of Water in Basin (kg)
11/18/2013	blank	3	B	no	11/18/2013 10:30	11/18/2013 12:30	120	26.22
11/18/2013	blank	3	C	na	11/18/2013 10:30	11/18/2013 12:30	120	27.46
11/19/2013	sample	1	A	na	11/19/2013 13:30	11/20/2013 10:08	1238	28.74
11/19/2013	sample	1	B	yes	11/19/2013 10:55	11/20/2013 22:08	2113	46.72
11/19/2013	sample	1	C	na	11/19/2013 13:30	11/20/2013 10:08	1238	36.12
11/19/2013	sample	2	A	na	11/19/2013 13:30	11/20/2013 10:08	1238	28.89
11/19/2013	sample	2	B	yes	11/19/2013 10:55	11/20/2013 22:08	2113	42.76
11/19/2013	sample	2	C	na	11/19/2013 13:30	11/20/2013 10:08	1238	30.94
11/19/2013	sample	3	A	na	11/19/2013 13:30	11/20/2013 10:08	1238	30.76
11/19/2013	sample	3	B	yes	11/19/2013 10:55	11/20/2013 22:08	2113	49.02
11/19/2013	sample	3	C	na	11/19/2013 13:30	11/20/2013 10:08	1238	32.26
11/21/2013	blank	1	A	na	11/21/2013 8:30	11/21/2013 10:30	120	30.16
11/21/2013	blank	1	B	yes	11/21/2013 8:30	11/21/2013 10:30	120	31.80
11/21/2013	blank	1	C	na	11/21/2013 8:30	11/21/2013 10:30	120	31.94
11/21/2013	blank	2	A	na	11/21/2013 8:30	11/21/2013 10:30	120	28.02
11/21/2013	blank	2	B	yes	11/21/2013 8:30	11/21/2013 10:30	120	30.62
11/21/2013	blank	2	C	na	11/21/2013 8:30	11/21/2013 10:30	120	28.02
11/21/2013	blank	3	A	na	11/21/2013 8:30	11/21/2013 10:30	120	22.10
11/21/2013	blank	3	B	yes	11/21/2013 8:30	11/21/2013 10:30	120	27.56
11/21/2013	blank	3	C	na	11/21/2013 8:30	11/21/2013 10:30	120	24.02
11/22/2013	sample	1	A	na	11/22/2013 7:00	11/22/2013 9:00	120	27.50
11/22/2013	sample	1	B	yes	11/22/2013 7:00	11/22/2013 9:00	120	29.76

Columns Run Date	Type of Run	BAM #	Column Type	Antibiotic	Start Time	End Time	Exact Flow duration (min)	Mass of Water in Basin (kg)
11/22/2013	sample	1	C	na	11/22/2013 7:00	11/22/2013 9:00	120	29.70
11/22/2013	sample	2	A	na	11/22/2013 7:00	11/22/2013 9:00	120	22.34
11/22/2013	sample	2	B	yes	11/22/2013 7:00	11/22/2013 9:00	120	30.94
11/22/2013	sample	2	C	na	11/22/2013 7:00	11/22/2013 9:00	120	33.34
11/22/2013	sample	3	A	na	11/22/2013 7:00	11/22/2013 9:00	120	23.44
11/22/2013	sample	3	B	yes	11/22/2013 7:00	11/22/2013 9:00	120	27.92
11/22/2013	sample	3	C	na	11/22/2013 7:00	11/22/2013 9:00	120	24.56
12/3/2013	sample	1	A	na	12/3/2013 10:57	12/4/2013 10:18	1401	30.06
12/3/2013	sample	1	B	yes	12/3/2013 10:57	12/4/2013 10:18	1401	40.60
12/3/2013	sample	1	C	na	12/3/2013 10:57	12/4/2013 10:18	1401	37.66
12/3/2013	sample	2	A	na	12/3/2013 10:57	12/4/2013 10:18	1401	29.56
12/3/2013	sample	2	B	yes	12/3/2013 10:57	12/4/2013 10:18	1401	31.48
12/3/2013	sample	2	C	na	12/3/2013 10:57	12/4/2013 10:18	1401	25.78
12/3/2013	sample	3	A	na	12/3/2013 10:57	12/4/2013 10:18	1401	36.44
12/3/2013	sample	3	B	yes	12/3/2013 10:57	12/4/2013 10:18	1401	35.62
12/3/2013	sample	3	C	na	12/3/2013 10:57	12/4/2013 10:18	1401	35.72
12/5/2013	blank	1	A	na	12/5/2013 7:00	12/5/2013 9:00	120	29.94
12/5/2013	blank	1	B	yes	12/5/2013 7:00	12/5/2013 9:00	120	26.97
12/5/2013	blank	1	C	na	12/5/2013 7:00	12/5/2013 9:00	120	27.50
12/5/2013	blank	2	A	na	12/5/2013 7:00	12/5/2013 9:00	120	28.54
12/5/2013	blank	2	B	yes	12/5/2013 7:00	12/5/2013 9:00	120	26.38
12/5/2013	blank	2	C	na	12/5/2013 7:00	12/5/2013 9:00	120	27.10

Columns Run Date	Type of Run	BAM #	Column Type	Antibiotic	Start Time	End Time	Exact Flow duration (min)	Mass of Water in Basin (kg)
12/5/2013	blank	3	A	na	12/5/2013 7:00	12/5/2013 9:00	120	26.10
12/5/2013	blank	3	B	yes	12/5/2013 7:00	12/5/2013 9:00	120	25.31
12/5/2013	blank	3	C	na	12/5/2013 7:00	12/5/2013 9:00	120	26.08
12/6/2013	sample	1	A	na	12/6/2013 7:00	12/6/2013 9:00	120	30.80
12/6/2013	sample	1	B	yes	12/6/2013 7:00	12/6/2013 9:00	120	28.70
12/6/2013	sample	1	C	na	12/6/2013 7:00	12/6/2013 9:00	120	27.98
12/6/2013	sample	2	A	na	12/6/2013 7:00	12/6/2013 9:00	120	28.54
12/6/2013	sample	2	B	yes	12/6/2013 7:00	12/6/2013 9:00	120	28.60
12/6/2013	sample	2	C	na	12/6/2013 7:00	12/6/2013 9:00	120	27.94
12/6/2013	sample	3	A	na	12/6/2013 7:00	12/6/2013 9:00	120	29.94
12/6/2013	sample	3	B	yes	12/6/2013 7:00	12/6/2013 9:00	120	27.98
12/6/2013	sample	3	C	na	12/6/2013 7:00	12/6/2013 9:00	120	27.54
12/9/2013	blank	1	A	na	12/9/2013 16:10	12/9/2013 18:10	120	30.66
12/9/2013	blank	1	B	yes	12/9/2013 16:10	12/9/2013 18:10	120	26.46
12/9/2013	blank	1	C	na	12/9/2013 16:10	12/9/2013 18:10	120	25.52
12/9/2013	blank	2	A	na	12/9/2013 16:10	12/9/2013 18:10	120	24.62
12/9/2013	blank	2	B	yes	12/9/2013 16:10	12/9/2013 18:10	120	25.02
12/9/2013	blank	2	C	na	12/9/2013 16:10	12/9/2013 18:10	120	24.38
12/9/2013	blank	3	A	na	12/9/2013 16:10	12/9/2013 18:10	120	26.20
12/9/2013	blank	3	B	yes	12/9/2013 16:10	12/9/2013 18:10	120	24.56
12/9/2013	blank	3	C	na	12/9/2013 16:10	12/9/2013 18:10	120	24.86
12/11/2013	sample	1	A	na	12/11/2013 7:00	12/11/2013 9:00	120	29.66

Columns Run Date	Type of Run	BAM #	Column Type	Antibiotic	Start Time	End Time	Exact Flow duration (min)	Mass of Water in Basin (kg)
12/11/2013	sample	1	B	yes	12/11/2013 7:00	12/11/2013 9:00	120	28.66
12/11/2013	sample	1	C	na	12/11/2013 7:00	12/11/2013 9:00	120	27.58
12/11/2013	sample	2	A	na	12/11/2013 7:00	12/11/2013 9:00	120	27.16
12/11/2013	sample	2	B	yes	12/11/2013 7:00	12/11/2013 9:00	120	27.88
12/11/2013	sample	2	C	na	12/11/2013 7:00	12/11/2013 9:00	120	26.96
12/11/2013	sample	3	A	na	12/11/2013 7:00	12/11/2013 9:00	120	25.16
12/11/2013	sample	3	B	yes	12/11/2013 7:00	12/11/2013 9:00	120	28.50
12/11/2013	sample	3	C	na	12/11/2013 7:00	12/11/2013 9:00	120	25.52
12/12/2013	sample	1	A	na	12/12/2013 9:00	12/13/2013 9:00	1440	41.30
12/12/2013	sample	1	B	yes	12/12/2013 9:00	12/13/2013 9:00	1440	41.90
12/12/2013	sample	1	C	na	12/12/2013 9:00	12/13/2013 9:00	1440	40.06
12/12/2013	sample	2	A	na	12/12/2013 9:00	12/13/2013 9:00	1440	34.70
12/12/2013	sample	2	B	yes	12/12/2013 9:00	12/13/2013 9:00	1440	35.42
12/12/2013	sample	2	C	na	12/12/2013 9:00	12/13/2013 9:00	1440	34.34
12/12/2013	sample	3	A	na	12/12/2013 9:00	12/13/2013 9:00	1440	36.08
12/12/2013	sample	3	B	yes	12/12/2013 9:00	12/13/2013 9:00	1440	39.86
12/12/2013	sample	3	C	na	12/12/2013 9:00	12/13/2013 9:00	1440	36.14

APPENDIX P
ANAMMOX PCR PRIMERS AND STANDARD

The Anammox PCR primers and positive control standard were manufactured by Integrated DNA Technologies® (IDT). The sequences for the Anammox primers were obtained from literature [116]. The Anammox positive control standard (gBlock®) was developed with the assistance of IDT technical support. The Specification Sheets for the primers and gBlock® are shown below. Note that there are two copies of the gBlock® Specification Sheet. The original gBlock® Specification Sheet from 2013 did not show the entire sequence due to character limit with the IDT software, note the ". . . . ." in the middle of the sequence. A reprint of the gBlock® Specification Sheet was requested in 2019 that shows the entire sequence. Both of these gBlock® Specification Sheets are shown below. The Anammox gBlock® sequence on the IDT Specification Sheets may be difficult to read so it is also shown in Table 75.

Table 75: Anammox Positive Control Sequence (gBlock® from IDT)

gBlock Name	Sequence (5'→3')	Length
Amx: AB775696.1	ACCGAGTGGCGTAAGGGTGAGTAATGCATTGATAACCTACCTATGAGACGGGGAT AACAACGTTCCGCAAGGGACTCCCGAAAGGGTTGCTAATACCCGATAAAACTCTTG ATGTTTAGGCATTGGGAGTCAAAGTTTGGGGCTGAAAGGTTCCATGTGCTCAGAG AGGGGTCAATGTCCTATCAGCTAGTTGGTAGGGTAAAGGCCTACCAAGGCGAAGA CGGGTAGCCGGCCTGAGAGGGTGGTCGGCCACATTGGGACTGAGACACTGCCCA GACTCCTACGGGAGGCTGCAGTCGAGAATCTTTCGCAATGCCCGGAAGGGTGACG AAGCGACGCCGCGTGTGGGAAGAAGGCCTTCGGGTTGTAAACCACTGTCGGGAG TTAAGAAGTGTAAGGGGGTGAATAGTCTCCTTACTTGACGTTAGCTCCGGAGGAA GCCACGGCTAACTCTGTGCCAGCAGCCGCGGTAATACAGAGGTGGCAAGCGTTGT TCGGAATTATTGGGCGTAAAGAGCACGTAGGCGGCCCTGCAAGTCAGCTGTGAAA TCCTTCTGCTCAACGGAAGAACGGCAGTTGATACTATGGGGCTCGAGTGCGGGAG GGGAGAGTGGAACTTCTGGTGGAGCGGTGAAATGCGTAGATATCAGAAGGAACA TCGGCGG	665bp

IDT®

INTEGRATED DNA TECHNOLOGIES

CIFICATION SHEET WWW.IDTDNA.COM

01-Oct-2013

Order No. **9998277**

Ref. No. **115384661**

Name - Amx: AB775696.1

gBlocks® Gene Fragments 665 base pairs

5' - ACC GAG TGG CGT AAG GGT GAG TAA TGC ATT GAT AAG GTA CCT ATG AGA CGG GGA TAA CAA CGT TCC
GCA AGG GAC TCC CGA AAG GGT TGC TAA TAC CCG ATA AAA CTC TTG ATG TTT AGG CAT TGG GAG TCA AAG
TTT GGG GCT GAA AGG TTC CAT GTG CTC AGA GAG GGG TCA ATG TCC TAT CAG CTA GTT GGT AGG GTA AAG
GCC TAC CAA GGC GAA GAC GGG TAG CCG GCC TGA GAG GGT GGT CGG CCA CAT TGG GAC TG . . . . . . TGA ?
ATA GTC TCC TTA CTT GAC GTT AGC TCC GGA GGA AGC CAC GGC TAA CTC TGT GCC AGC AGC CGC GGT AAT
ACA GAG GTG GCA AGC GTT GTT CGG AAT TAT TGG GCG TAA AGA GCA CGT AGG CGG CCC TGC AAG TCA GCT
GTG AAA TCC TTC TGC TCA ACG GAA GAA CGG CAG TTG ATA CTA TGG GGC TCG AGT GCG GGA GGG GAG AGT
GGA ACT TCT GGT GGA GCG GTG AAA TGC GTA GAT ATC AGA AGG AAC ATC GGC GG - 3'

Note: gBlocks® Gene Fragments are delivered as double-standed DNA. The above is the sequence of the sense strand. Each gBlocks Gene Fragment has been sequenced verified to ensure the consensus sequence is correct.

Properties

Length:	665
Amount Delivered:	200ng
GC Content:	54.29%
Molecular Weight:	410806.7
oles/ng:	2.43
OD_{260}:	50

Shipped To

UNIVERSITY OF CENTRAL FLORIDA-ORLAN
12800 PEGASUS DR SUTE 211
CIVIL, ENVIRON, CONSTRUCTION ENGINE
ORLANDO, FL 32816

Customer No. 263437

Modifications & Services

Disclaimer

See on reverse page notes (I) (II) & (III) for usage, label license, and product warranties

Labels - Peel Here

115384661 IDT
Andrew Randall
167057065 01-Oct-2013
gBlocks® Gene Fragments
Amx: AB775696.1
200ng=400 fmol, lyophilized

115384661 IDT
Andrew Randall
167057065 01-Oct-2013
gBlocks® Gene Fragments
Amx: AB775696.1
200ng=400 fmol, lyophilized

I N S T R U C T I O N S

•Lyophilized contents may appear as either a translucent film or a white powder. This variance does not affect the quality of the oligos.

leuse centrifuge tubes prior to opening. Some of the product may e been dislodged during shipping.

15 November 2019

Sales Order Number **9998277**

Reference Number **115384661**

Customer Name - Andrew Randall

Name - Amx: AB775696.1

gBlocks® Gene Fragments 665 base pairs

```
5'- ACC GAG TGG CGT AAG GGT GAG TAA TGC ATT GAT AAC CTA CCT ATG AGA CGG GGA TAA CAA CGT TCC GCA
AGG GAC TCC CGA AAG GGT TGC TAA TAC CCG ATA AAA CTC TTG ATG TTT AGG CAT TGG GAG TCA AAG TTT GGG
GCT GAA AGG TTC CAT GTG CTC AGA GAG GGG TCA ATG TCC TAT CAG CTA GTT GGT AGG GTA AAG GCC TAC CAA
GGC GAA GAC GGG TAG CCG GCC TGA GAG GGT GGT CGG CCA CAT TGG GAC TGA GAC ACT GCC CAG ACT CCT ACG
GGA GGC TGC AGT CGA GAA TCT TTC GCA ATG CCC GGA AGG GTG ACG AAG CGA CGC CGC GTG TGG GAA GAA GGC
CTT CGG GTT GTA AAC CAC TGT CGG GAG TTA AGA AGT GTA AGG GGG TGA ATA GTC TCC TTA CTT GAC GTT AGC
TCC GGA GGA AGC CAC GGC TAA CTC TGT GCC AGC AGC CGC GGT AAT ACA GAG GTG GCA AGC GTT GTT CGG AAT
TAT TGG GCG TAA AGA GCA CGT AGG CGG CCC TGC AAG TCA GCT GTG AAA TCC TTC TGC TCA ACG GAA GAA CGG
CAG TTG ATA CTA TGG GGC TCG AGT GCG GGA GGG GAG AGT GGA ACT TCT GGT GGA GCG GTG AAA TGC GTA GAT
ATC AGA AGG AAC ATC GGC GG -3'
```

Note 1: The sequence information of the sense strand displayed above is intentionally truncated to the first 1,200 bases. The complete sequence can be verified in FASTA format in your order history.

Note 2: gBlocks® Gene Fragments are delivered as double-stranded DNA. Conformance to quality standards is established in multiple ways, including size verification by capillary electrophoresis and sequence identification by mass spectrometry.

Properties

Length:	665
Amount Delivered:	200ng
GC Content:	54.29%
Molecular Weight:	410806.7
fmoles/ng:	2.43
µg/OD260:	50

115384661 IDT
Andrew Randall
167047838 15-Nov-2019
gBlocks® Gene Fragments
Amx: AB775696.1
200ng :: 487fmol, dried

115384661 IDT
Andrew Randall
167047838 15-Nov-2019
gBlocks® Gene Fragments
Amx: AB775696.1
200ng :: 487fmol, dried

Disclaimer

See page notes (I), (II), & (III) on reverse for usage, label license, and product warranties

Instructions

Dried contents may appear as either a translucent film or a white powder. This variance does not affect the quality of the gBlocks® Gene Fragments.

Resuspending your gBlocks® Gene Fragments

1. Prior to opening, centrifuge the tube at a minimum of 3000 x g to ensure that the material is at the bottom of the tube.
2. Add TE to reach a final concentration of 10ng/µL.
3. Vortex briefly.
4. Incubate at 50°C for 20 minutes.
5. Briefly vortex and centrifuge.

Amplifying your gBlocks® Gene Fragments

- For gBlocks® Gene Fragments ≤1kb, amplification can be performed using a high fidelity polymerase. To avoid sequence mutations due to amplification errors limit cycles to 12 or fewer.
- For gBlocks® Gene Fragments >1kb, we do not recommend amplification.

For additional information please see www.idtdna.com/gblockssupport or contact genes@idtdna.com

INTEGRATED DNA TECHNOLOGIES

OLIGONUCLEOTIDE SPECIFICATION SHEET

20-Sep-2013

Order No. **9998277**

Ref. No. **115384668**

Sequence - Amx-F (Pla46F)

25 nmole DNA Oligo, 18 bases

5'- GGA TTA GGC ATG CAA GTC -3'

Properties

*Tm (50mM NaCl)**: 50.8 °C
GC Content: 50.0%
Molecular Weight: 5,563.7
nmoles/OD260: 5.5
ug/OD260: 30.9
Ext. Coefficient: 180,300 L/(mole·cm)

Amount Of Oligo

6.2=	34.5	=0.19
OD_{260}	nmoles	mg

For 100 µM: add 345 µL

Shipped To

ANDREW RANDALL
UNIVERSITY OF CENTRAL FLORIDA-ORLA
12800 PEGASUS DR SUTE 211
ORLANDO, FL 32816
USA
407-823-6429
Customer No. 263437 *PO No. Credit Card*

Secondary Structure Calculations

Lowest folding free energy (kcal/mole): 1.31 at 25 °C
Strongest Folding Tm: -12.6 °C

Oligo Base Types	Quantity
DNA Bases	18
Modifications and Services	Quantity
Standard Desalting	1

Disclaimer

See on reverse page notes (I) (II) & (III) for usage, label license, and product warranties

Mfg. ID 45735039

115384668 IDT
A.RANDALL
45735039 20-Sep-2013
Amx-F (Pla46F)

115384668 IDT
A.RANDALL
45735039 20-Sep-2013
Amx-F (Pla46F)

INSTRUCTIONS

•Lyophilized contents may appear as either a translucent film or a white powder. This variance does not affect the quality of the oligo.

•Please centrifuge tubes prior to opening. Some of the product may have been dislodged during shipping.

*The Tm shown takes no account of Mg^{2+} and dNTP concentrations. Use the OligoAnalyzer® Program at www.idtdna.com/scitools to calculate accurate Tm for your reaction conditions.

M

INTEGRATED DNA TECHNOLOGIES

OLIGONUCLEOTIDE SPECIFICATION SHEET

20-Sep-2013

Order No. **9998277**

Ref. No. **115384669**

Sequence - Amx667R

25 nmole DNA Oligo, 18 bases

5'- ACC AGA AGT TCC ACT CTC -3'

Properties

*Tm (50mM NaCl)**: 51.0 °C
GC Content: 50.0%
Molecular Weight: 5,403.6
nmoles/OD260: 5.9
ug/OD260: 32.0
Ext. Coefficient: 168,600 L/(mole·cm)

Amount Of Oligo

4.4 = OD_{260} 26.4 nmoles   = 0.14 mg

For 100 µM: add 264 µL

Shipped To

ANDREW RANDALL
UNIVERSITY OF CENTRAL FLORIDA-ORLA
12800 PEGASUS DR SUTE 211
ORLANDO, FL 32816
USA
407-823-6429
Customer No. 263437   *PO No. Credit Card*

Secondary Structure Calculations

Lowest folding free energy (kcal/mole): 0.59 at 25 °C
Strongest Folding Tm: 10.3 °C

Oligo Base Types	Quantity
DNA Bases	18
Modifications and Services	Quantity
Standard Desalting	1

Disclaimer

See on reverse page notes (I) (II) & (III) for usage, label license, and product warranties

Mfg. ID 45735040

115384669 A.RANDALL 45735040 20-Sep-2013 Amx667R 5'-ACC AGA AGT TCC ACT CTC-3' MW= 5,403.6g/mol Tm= 51.0°C 4.4OD = 26.4nmol= 0.14mg

115384669 A.RANDALL 45735040 20-Sep-2013 Amx667R 5'-ACC AGA AGT TCC ACT CTC-3' MW= 5,403.6g/mol Tm= 51.0°C 4.4OD = 26.4nmol= 0.14mg

I N S T R U C T I O N S

•Lyophilized contents may appear as either a translucent film or a white powder. This variance does not affect the quality of the oligo.

•Please centrifuge tubes prior to opening. Some of the product may have been dislodged during shipping.

*The Tm shown takes no account of Mg^{2+} and dNTP concentrations. Use the OligoAnalyzer® Program at www.idtdna.com/scitools to calculate accurate Tm for your reaction conditions.

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APPENDIX Q
NITROGEN

Table 76: Raw Nitrogen Data for BAM #1, A & B Columns, 22-minute EBCT

Approximate Flow Duration (hours)	Columns Run Date	Column Media #	Column Type	ERD Analyzed: Influent TN (mg/L as N)	ERD Analyzed: Effluent TN (mg/L as N)	ERD Analyzed: Influent NOx (mg/L as N)	ERD Analyzed: Effluent NOx (mg/L as N)	ERD Analyzed: Influent NH_3 (mg/L as N)	ERD Analyzed: Effluent NH_3 (mg/L as N)
2	9/27/2013	1	A	2.023	1.161	0.244	0.326	0.649	0.415
2	9/27/2013	1	B	2.023	1.106	0.244	0.375	0.649	0.390
2	10/4/2013	1	A	1.586	1.165	0.325	0.473	0.942	0.256
2	10/4/2013	1	B	1.586	1.380	0.325	0.547	0.942	0.268
2	10/18/2013	1	A	1.768	1.465	0.215	0.470	0.708	0.244
2	10/18/2013	1	B	1.768	1.480	0.215	0.397	0.708	0.352
2	10/25/2013	1	A	1.600	1.175	0.208	0.267	0.643	0.398
2	10/25/2013	1	B	1.600	1.186	0.208	0.314	0.643	0.359
2	11/1/2013	1	A	1.533	1.145	0.206	0.296	0.858	0.492
2	11/1/2013	1	B	1.533	1.675	0.206	0.416	0.858	0.448
2	11/8/2013	1	A	1.653	1.152	0.238	0.364	0.640	0.328
2	11/8/2013	1	B	1.653	1.192	0.238	0.501	0.640	0.229
2	11/15/2013	1	A	1.491	1.182	0.237	0.395	0.618	0.350
2	11/22/2013	1	A	1.672	1.392	0.344	0.493	0.780	0.412
2	12/6/2013	1	A	1.548	1.295	0.256	0.408	0.482	0.239
2	12/11/2013	1	A	1.421	1.338	0.233	0.384	0.718	0.247
			median	1.600	1.189	0.238	0.396	0.679	0.351

Table 77: Calculated Nitrogen Data for BAM #1, A & B Columns, 22-minute EBCT

Columns Run Date	Column Type	Influent Organic Nitrogen (mg/L as N)	Effluent Organic Nitrogen (mg/L as N)	Δ Organic Nitrogen (mg/L as N)	Influent Inorganic Nitrogen (mg/L as N)	Effluent Inorganic Nitrogen (mg/L as N)	Δ Inorganic Nitrogen (mg/L as N)	Δ TN (mg/L as N)	% Removal of TN	Δ NOx (mg/L as N)	Δ NH_3 (mg/L as N)
9/27/2013	A	1.130	0.420	-0.710	0.893	0.741	-0.152	-0.862	43%	0.082	-0.234
9/27/2013	B	1.130	0.341	-0.789	0.893	0.765	-0.128	-0.917	45%	0.131	-0.259
10/4/2013	A	0.319	0.436	0.117	1.267	0.729	-0.538	-0.421	27%	0.148	-0.686
10/4/2013	B	0.319	0.565	0.246	1.267	0.815	-0.452	-0.206	13%	0.222	-0.674
10/18/2013	A	0.845	0.751	-0.094	0.923	0.714	-0.209	-0.303	17%	0.255	-0.464
10/18/2013	B	0.845	0.731	-0.114	0.923	0.749	-0.174	-0.288	16%	0.182	-0.356
10/25/2013	A	0.749	0.510	-0.239	0.851	0.665	-0.186	-0.425	27%	0.059	-0.245
10/25/2013	B	0.749	0.513	-0.236	0.851	0.673	-0.178	-0.414	26%	0.106	-0.284
11/1/2013	A	0.469	0.357	-0.112	1.064	0.788	-0.276	-0.388	25%	0.090	-0.366
11/1/2013	B	0.469	0.811	0.342	1.064	0.864	-0.200	0.142	-9%	0.210	-0.410
11/8/2013	A	0.775	0.460	-0.315	0.878	0.692	-0.186	-0.501	30%	0.126	-0.312
11/8/2013	B	0.775	0.462	-0.313	0.878	0.730	-0.148	-0.461	28%	0.263	-0.411
11/15/2013	A	0.636	0.437	-0.199	0.855	0.745	-0.110	-0.309	21%	0.158	-0.268
11/22/2013	A	0.548	0.487	-0.061	1.124	0.905	-0.219	-0.280	17%	0.149	-0.368
12/6/2013	A	0.810	0.648	-0.162	0.738	0.647	-0.091	-0.253	16%	0.152	-0.243
12/11/2013	A	0.470	0.707	0.237	0.951	0.631	-0.320	-0.083	6%	0.151	-0.471
	median	0.749	0.499	-0.138	0.908	0.736	-0.186	-0.349	23%	0.150	-0.361

Note:
Δ = Effluent – Influent, thus a positive Δ indicates an increase and a negative Δ indicates a decrease.

Table 78: Raw & Calculated Nitrogen Data for BAM #1, C Columns, 22-minute EBCT

Approximate Flow Duration (hours)	Columns Run Date	Column Media #	Column Type	ERD Analyzed: Influent NOx (mg/L as N)	ERD Analyzed: Effluent NOx (mg/L as N)	ERD Analyzed: Influent NH_3 (mg/L as N)	ERD Analyzed: Effluent NH_3 (mg/L as N)	Δ NH_3 (mg/L as N)	Δ NOx (mg/L as N)
2	9/27/2013	1	C	0.230	0.174	0.672	0.597	-0.075	-0.056
2	10/4/2013	1	C	0.230	0.173	0.904	0.656	-0.248	-0.057
2	10/18/2013	1	C	0.204	0.141	0.679	0.712	0.033	-0.063
2	10/25/2013	1	C	0.196	0.167	0.658	0.695	0.037	-0.029
2	11/1/2013	1	C	0.208	0.170	0.899	0.904	0.005	-0.038
2	11/8/2013	1	C	0.226	0.189	0.644	0.579	-0.065	-0.037
2	11/15/2013	1	C	0.234	0.196	0.693	0.650	-0.043	-0.038
2	11/22/2013	1	C	0.271	0.225	0.845	0.682	-0.163	-0.046
2	12/6/2013	1	C	0.237	0.199	0.479	0.484	0.005	-0.038
2	12/11/2013	1	C	0.236	0.190	0.736	0.502	-0.234	-0.046
			Median	0.230	0.182	0.686	0.653	-0.054	-0.042

Note:
Δ = Effluent – Influent, thus a positive Δ indicates an increase and a negative Δ indicates a decrease.

Table 79: Raw Nitrogen Data for BAM #1, A & B Columns, 220-minute EBCT

Approximate Flow Duration (hours)	Columns Run Date	Column Media #	Column Type	ERD Analyzed: Influent TN (mg/L as N)	ERD Analyzed: Effluent TN (mg/L as N)	ERD Analyzed: Influent NOx (mg/L as N)	ERD Analyzed: Effluent NOx (mg/L as N)	ERD Analyzed: Influent NH_3 (mg/L as N)	ERD Analyzed: Effluent NH_3 (mg/L as N)
24	9/24/2013	1	A	1.267	1.382	0.308	0.022	0.659	0.673
24	9/24/2013	1	B	1.267	4.821	0.308	0.014	0.659	0.283
24	10/1/2013	1	A	1.664	0.904	0.515	0.009	0.609	0.333
24	10/1/2013	1	B	1.664	0.823	0.515	0.031	0.609	0.241
24	10/8/2013	1	A	1.444	0.740	0.329	0.021	0.735	0.261
24	10/8/2013	1	B	1.444	0.551	0.329	0.020	0.735	0.078
24	10/15/2013	1	A	1.781	0.846	0.233	0.017	0.815	0.382
24	10/15/2013	1	B	1.781	0.734	0.233	0.013	0.815	0.260
24	10/29/2013	1	A	1.623	0.786	0.258	0.070	0.793	0.236
24	10/29/2013	1	B	1.623	0.755	0.258	0.026	0.793	0.280
24	11/5/2013	1	A	1.594	0.755	0.261	0.013	0.660	0.204
24	11/5/2013	1	B	1.594	0.797	0.261	0.066	0.660	0.116
24	11/12/2013	1	A	1.747	1.028	0.348	0.306	0.763	0.113
24	11/12/2013	1	B	1.747	0.946	0.348	0.650	0.763	0.051
24	11/19/2013	1	A	1.528	0.598	0.330	0.133	0.571	0.003
24	12/3/2013	1	A	0.834	0.711	0.261	0.282	0.492	0.003
24	12/12/2013	1	A	1.142	0.615	0.327	0.488	0.757	0.012
			median	1.594	0.786	0.308	0.026	0.735	0.236

Table 80: Calculated Nitrogen Data for BAM #1, A & B Columns, 220-minute EBCT

Columns Run Date	Column Type	Influent Organic Nitrogen (mg/L as N)	Effluent Organic Nitrogen (mg/L as N)	Δ Organic Nitrogen (mg/L as N)	Influent Inorganic Nitrogen (mg/L as N)	Effluent Inorganic Nitrogen (mg/L as N)	Δ Inorganic Nitrogen (mg/L as N)	Δ TN (mg/L as N)	% Removal of TN	Δ NOx (mg/L as N)	Δ NH_3 (mg/L as N)
9/24/2013	A	0.300	0.687	0.387	0.967	0.695	-0.272	0.115	-9%	-0.286	0.014
9/24/2013	B	0.300	4.524	4.224	0.967	0.297	-0.670	3.554	-281%	-0.294	-0.376
10/1/2013	A	0.540	0.562	0.022	1.124	0.342	-0.782	-0.760	46%	-0.506	-0.276
10/1/2013	B	0.540	0.551	0.011	1.124	0.272	-0.852	-0.841	51%	-0.484	-0.368
10/8/2013	A	0.380	0.458	0.078	1.064	0.282	-0.782	-0.704	49%	-0.308	-0.474
10/8/2013	B	0.380	0.453	0.073	1.064	0.098	-0.966	-0.893	62%	-0.309	-0.657
10/15/2013	A	0.733	0.447	-0.286	1.048	0.399	-0.649	-0.935	52%	-0.216	-0.433
10/15/2013	B	0.733	0.461	-0.272	1.048	0.273	-0.775	-1.047	59%	-0.220	-0.555
10/29/2013	A	0.572	0.480	-0.092	1.051	0.306	-0.745	-0.837	52%	-0.188	-0.557
10/29/2013	B	0.572	0.449	-0.123	1.051	0.306	-0.745	-0.868	53%	-0.232	-0.513
11/5/2013	A	0.673	0.538	-0.135	0.921	0.217	-0.704	-0.839	53%	-0.248	-0.456
11/5/2013	B	0.673	0.615	-0.058	0.921	0.182	-0.739	-0.797	50%	-0.195	-0.544
11/12/2013	A	0.636	0.609	-0.027	1.111	0.419	-0.692	-0.719	41%	-0.042	-0.650
11/12/2013	B	0.636	0.245	-0.391	1.111	0.701	-0.410	-0.801	46%	0.302	-0.712
11/19/2013	A	0.627	0.462	-0.165	0.901	0.136	-0.765	-0.930	61%	-0.197	-0.568
12/3/2013	A	0.081	0.426	0.345	0.753	0.285	-0.468	-0.123	15%	0.021	-0.489
12/12/2013	A	0.058	0.115	0.057	1.084	0.500	-0.584	-0.527	46%	0.161	-0.745
	median	0.572	0.462	-0.027	1.051	0.297	-0.739	-0.801	50%	-0.220	-0.513

Note:
Δ = Effluent – Influent, thus a positive Δ indicates an increase and a negative Δ indicates a decrease.

Table 81: Raw & Calculated Nitrogen Data for BAM #1, C Columns, 220-minute EBCT

Approximate Flow Duration (hours)	Columns Run Date	Column Media #	Column Type	ERD Analyzed: Influent NOx (mg/L as N)	ERD Analyzed: Effluent NOx (mg/L as N)	ERD Analyzed: Influent NH_3 (mg/L as N)	ERD Analyzed: Effluent NH_3 (mg/L as N)	Δ NH_3 (mg/L as N)	Δ NOx (mg/L as N)
24	9/24/2013	1	C	0.251	0.026	0.77	0.899	0.129	-0.225
24	10/1/2013	1	C	0.28	0.011	0.824	0.816	-0.008	-0.269
24	10/8/2013	1	C	0.247	0.004	0.719	0.728	0.009	-0.243
24	10/15/2013	1	C	0.229	0.009	0.792	0.886	0.094	-0.22
24	10/22/2013	1	C	0.264	0.006	0.53	0.754	0.224	-0.258
24	10/29/2013	1	C	0.229	0.005	0.956	0.621	-0.335	-0.224
24	11/5/2013	1	C	0.224	0.021	0.76	0.536	-0.224	-0.203
24	11/12/2013	1	C	0.27	0.022	0.898	0.676	-0.222	-0.248
24	11/19/2013	1	C	0.228	0.023	0.729	0.454	-0.275	-0.205
24	12/3/2013	1	C	0.232	0.035	0.608	0.69	0.082	-0.197
24	12/12/2013	1	C	0.244	0.079	0.786	0.631	-0.155	-0.165
			Median	0.244	0.021	0.77	0.69	-0.008	-0.224

Note:
Δ = Effluent – Influent, thus a positive Δ indicates an increase and a negative Δ indicates a decrease.

Table 82: Raw Nitrogen Data for BAM #2, A & B Columns, 22-minute EBCT

Approximate Flow Duration (hours)	Columns Run Date	Column Media #	Column Type	ERD Analyzed: Influent TN (mg/L as N)	ERD Analyzed: Effluent TN (mg/L as N)	ERD Analyzed: Influent NOx (mg/L as N)	ERD Analyzed: Effluent NOx (mg/L as N)	ERD Analyzed: Influent NH_3 (mg/L as N)	ERD Analyzed: Effluent NH_3 (mg/L as N)
2	9/27/2013	2	A	2.023	1.442	0.244	0.45	0.649	0.523
2	9/27/2013	2	B	2.023	1.594	0.244	0.463	0.649	0.456
2	10/4/2013	2	A	1.586	1.487	0.325	0.644	0.942	0.441
2	10/4/2013	2	B	1.586	1.44	0.325	0.634	0.942	0.241
2	10/18/2013	2	A	1.768	1.455	0.215	0.444	0.708	0.450
2	10/18/2013	2	B	1.768	1.559	0.215	0.446	0.708	0.468
2	10/25/2013	2	A	1.600	1.368	0.208	0.306	0.643	0.441
2	10/25/2013	2	B	1.600	1.419	0.208	0.371	0.643	0.429
2	11/1/2013	2	A	1.533	1.298	0.206	0.398	0.858	0.576
2	11/1/2013	2	B	1.533	1.417	0.206	0.409	0.858	0.537
2	11/8/2013	2	A	1.653	1.401	0.238	0.495	0.64	0.366
2	11/8/2013	2	B	1.653	1.459	0.238	0.52	0.64	0.331
2	11/15/2013	2	A	1.491	1.38	0.237	0.519	0.618	0.343
2	11/15/2013	2	B	1.491	1.281	0.237	0.542	0.618	0.329
2	11/22/2013	2	A	1.672	1.405	0.344	0.632	0.78	0.331
2	12/6/2013	2	A	1.548	1.313	0.256	0.498	0.482	0.207
2	12/11/2013	2	A	1.421	1.542	0.233	0.51	0.718	0.295
			median	1.600	1.419	0.237	0.495	0.649	0.429

Table 83: Calculated Nitrogen Data for BAM #2, A & B Columns, 22-minute EBCT

Columns Run Date	Column Type	Influent Organic Nitrogen (mg/L as N)	Effluent Organic Nitrogen (mg/L as N)	Δ Organic Nitrogen (mg/L as N)	Influent Inorganic Nitrogen (mg/L as N)	Effluent Inorganic Nitrogen (mg/L as N)	Δ Inorganic Nitrogen (mg/L as N)	Δ TN (mg/L as N)	% Removal of TN	Δ NOx (mg/L as N)	Δ NH_3 (mg/L as N)
9/27/2013	A	1.130	0.469	-0.661	0.893	0.973	0.080	-0.581	28.7%	0.206	-0.126
9/27/2013	B	1.130	0.675	-0.455	0.893	0.919	0.026	-0.429	21.2%	0.219	-0.193
10/4/2013	A	0.319	0.402	0.083	1.267	1.085	-0.182	-0.099	6.2%	0.319	-0.501
10/4/2013	B	0.319	0.565	0.246	1.267	0.875	-0.392	-0.146	9.2%	0.309	-0.701
10/18/2013	A	0.845	0.561	-0.284	0.923	0.894	-0.029	-0.313	17.7%	0.229	-0.258
10/18/2013	B	0.845	0.645	-0.200	0.923	0.914	-0.009	-0.209	11.8%	0.231	-0.240
10/25/2013	A	0.749	0.621	-0.128	0.851	0.747	-0.104	-0.232	14.5%	0.098	-0.202
10/25/2013	B	0.749	0.619	-0.130	0.851	0.800	-0.051	-0.181	11.3%	0.163	-0.214
11/1/2013	A	0.469	0.324	-0.145	1.064	0.974	-0.090	-0.235	15.3%	0.192	-0.282
11/1/2013	B	0.469	0.471	0.002	1.064	0.946	-0.118	-0.116	7.6%	0.203	-0.321
11/8/2013	A	0.775	0.540	-0.235	0.878	0.861	-0.017	-0.252	15.2%	0.257	-0.274
11/8/2013	B	0.775	0.608	-0.167	0.878	0.851	-0.027	-0.194	11.7%	0.282	-0.309
11/15/2013	A	0.636	0.518	-0.118	0.855	0.862	0.007	-0.111	7.4%	0.282	-0.275
11/15/2013	B	0.636	0.410	-0.226	0.855	0.871	0.016	-0.210	14.1%	0.305	-0.289
11/22/2013	A	0.548	0.442	-0.106	1.124	0.963	-0.161	-0.267	16.0%	0.288	-0.449
12/6/2013	A	0.810	0.608	-0.202	0.738	0.705	-0.033	-0.235	15.2%	0.242	-0.275
12/11/2013	A	0.470	0.737	0.267	0.951	0.805	-0.146	0.121	-8.5%	0.277	-0.423
	median	0.749	0.561	-0.145	0.893	0.875	-0.033	-0.210	14%	0.242	-0.275

Note:
Δ = Effluent – Influent, thus a positive Δ indicates an increase and a negative Δ indicates a decrease.

Table 84: Raw & Calculated Nitrogen Data for BAM #2, C Columns, 22-minute EBCT

Approximate Flow Duration (hours)	Columns Run Date	Column Media #	Column Type	ERD Analyzed: Influent NOx (mg/L as N)	ERD Analyzed: Effluent NOx (mg/L as N)	ERD Analyzed: Influent NH_3 (mg/L as N)	ERD Analyzed: Effluent NH_3 (mg/L as N)	Δ NH_3 (mg/L as N)	Δ NOx (mg/L as N)
2	9/27/2013	2	C	0.23	0.209	0.672	0.827	0.155	-0.021
2	10/4/2013	2	C	0.23	0.208	0.904	0.856	-0.048	-0.022
2	10/18/2013	2	C	0.204	0.179	0.679	0.762	0.083	-0.025
2	10/25/2013	2	C	0.196	0.173	0.658	0.698	0.04	-0.023
2	11/1/2013	2	C	0.208	0.194	0.899	0.883	-0.016	-0.014
2	11/8/2013	2	C	0.226	0.214	0.644	0.653	0.009	-0.012
2	11/15/2013	2	C	0.234	0.217	0.693	0.728	0.035	-0.017
2	11/22/2013	2	C	0.271	na	0.845	0.76	-0.085	NA
2	12/6/2013	2	C	0.237	2.533	0.479	0.531	0.052	2.296
2	12/11/2013	2	C	0.236	0.216	0.736	0.71	-0.026	-0.02
			Median	0.230	0.209	0.686	0.744	0.022	-0.020

Note:
Δ = Effluent – Influent, thus a positive Δ indicates an increase and a negative Δ indicates a decrease.

Table 85: Raw Nitrogen Data for BAM #2, A & B Columns, 220-minute EBCT

Approximate Flow Duration (hours)	Columns Run Date	Column Media #	Column Type	ERD Analyzed: Influent TN (mg/L as N)	ERD Analyzed: Effluent TN (mg/L as N)	ERD Analyzed: Influent NOx (mg/L as N)	ERD Analyzed: Effluent NOx (mg/L as N)	ERD Analyzed: Influent NH_3 (mg/L as N)	ERD Analyzed: Effluent NH_3 (mg/L as N)
24	9/24/2013	2	A	1.267	1.110	0.308	0.719	0.659	0.111
24	9/24/2013	2	B	1.267	1.089	0.308	0.653	0.659	0.164
24	10/1/2013	2	A	1.664	1.355	0.515	0.618	0.609	0.281
24	10/1/2013	2	B	1.664	1.149	0.515	0.418	0.609	0.355
24	10/8/2013	2	A	1.444	1.260	0.329	0.801	0.735	0.060
24	10/8/2013	2	B	1.444	1.042	0.329	0.636	0.735	0.131
24	10/15/2013	2	A	1.781	1.034	0.233	0.221	0.815	0.312
24	10/15/2013	2	B	1.781	0.924	0.233	0.021	0.815	0.524
24	10/29/2013	2	A	1.623	1.357	0.258	0.757	0.793	0.129
24	10/29/2013	2	B	1.623	1.309	0.258	0.561	0.793	0.239
24	11/5/2013	2	A	1.594	1.294	0.261	0.651	0.660	0.079
24	11/5/2013	2	B	1.594	1.150	0.261	0.457	0.660	0.161
24	11/12/2013	2	A	1.747	1.617	0.348	1.047	0.763	0.085
24	11/12/2013	2	B	1.747	1.557	0.348	0.832	0.763	0.189
24	11/19/2013	2	A	1.528	1.220	0.330	0.714	0.571	0.003
24	12/3/2013	2	A	0.834	1.268	0.261	0.959	0.492	0.003
24	12/12/2013	2	A	1.142	1.180	0.327	1.167	0.757	0.003
			median	1.594	1.22	0.308	0.653	0.735	0.131

Table 86: Calculated Nitrogen Data for BAM #2, A & B Columns, 220-minute EBCT

Columns Run Date	Column Type	Influent Organic Nitrogen (mg/L as N)	Effluent Organic Nitrogen (mg/L as N)	Δ Organic Nitrogen (mg/L as N)	Influent Inorganic Nitrogen (mg/L as N)	Effluent Inorganic Nitrogen (mg/L as N)	Δ Inorganic Nitrogen (mg/L as N)	Δ TN (mg/L as N)	% Removal of TN	Δ NOx (mg/L as N)	Δ NH_3 (mg/L as N)
9/24/2013	A	0.300	0.280	-0.020	0.967	0.830	-0.137	-0.157	12%	0.411	-0.548
9/24/2013	B	0.300	0.272	-0.028	0.967	0.817	-0.150	-0.178	14%	0.345	-0.495
10/1/2013	A	0.540	0.456	-0.084	1.124	0.899	-0.225	-0.309	19%	0.103	-0.328
10/1/2013	B	0.540	0.376	-0.164	1.124	0.773	-0.351	-0.515	31%	-0.097	-0.254
10/8/2013	A	0.380	0.399	0.019	1.064	0.861	-0.203	-0.184	13%	0.472	-0.675
10/8/2013	B	0.380	0.275	-0.105	1.064	0.767	-0.297	-0.402	28%	0.307	-0.604
10/15/2013	A	0.733	0.501	-0.232	1.048	0.533	-0.515	-0.747	42%	-0.012	-0.503
10/15/2013	B	0.733	0.379	-0.354	1.048	0.545	-0.503	-0.857	48%	-0.212	-0.291
10/29/2013	A	0.572	0.471	-0.101	1.051	0.886	-0.165	-0.266	16%	0.499	-0.664
10/29/2013	B	0.572	0.509	-0.063	1.051	0.800	-0.251	-0.314	19%	0.303	-0.554
11/5/2013	A	0.673	0.564	-0.109	0.921	0.730	-0.191	-0.300	19%	0.390	-0.581
11/5/2013	B	0.673	0.532	-0.141	0.921	0.618	-0.303	-0.444	28%	0.196	-0.499
11/12/2013	A	0.636	0.485	-0.151	1.111	1.132	0.021	-0.130	7%	0.699	-0.678
11/12/2013	B	0.636	0.536	-0.100	1.111	1.021	-0.090	-0.190	11%	0.484	-0.574
11/19/2013	A	0.627	0.503	-0.124	0.901	0.717	-0.184	-0.308	20%	0.384	-0.568
12/3/2013	A	0.081	0.306	0.225	0.753	0.962	0.209	0.434	-52%	0.698	-0.489
12/12/2013	A	0.058	0.010	-0.048	1.084	1.170	0.086	0.038	-3%	0.840	-0.754
	median	0.572	0.456	-0.101	1.051	0.817	-0.191	-0.300	19%	0.384	-0.554

Note:
Δ = Effluent – Influent, thus a positive Δ indicates an increase and a negative Δ indicates a decrease.

Table 87: Raw & Calculated Nitrogen Data for BAM #2, C Columns, 220-minute EBCT

Approximate Flow Duration (hours)	Columns Run Date	Column Media #	Column Type	ERD Analyzed: Influent NOx (mg/L as N)	ERD Analyzed: Effluent NOx (mg/L as N)	ERD Analyzed: Influent NH_3 (mg/L as N)	ERD Analyzed: Effluent NH_3 (mg/L as N)	Δ NH_3 (mg/L as N)	Δ NOx (mg/L as N)
24	9/24/2013	2	C	0.251	0.116	0.770	0.847	0.077	-0.135
24	10/1/2013	2	C	0.280	0.050	0.824	1.190	0.366	-0.230
24	10/8/2013	2	C	0.247	0.196	0.719	0.791	0.072	-0.051
24	10/15/2013	2	C	0.229	0.081	0.792	0.820	0.028	-0.148
24	10/22/2013	2	C	0.264	0.093	0.530	0.708	0.178	-0.171
24	10/29/2013	2	C	0.229	0.132	0.956	0.928	-0.028	-0.097
24	11/5/2013	2	C	0.224	0.161	0.760	0.545	-0.215	-0.063
24	11/12/2013	2	C	0.270	0.236	0.898	0.742	-0.156	-0.034
24	11/19/2013	2	C	0.228	0.211	0.729	0.603	-0.126	-0.017
24	12/3/2013	2	C	0.232	0.220	0.608	0.483	-0.125	-0.012
24	12/12/2013	2	C	0.244	0.254	0.786	0.718	-0.068	0.010
			Median	0.244	0.161	0.77	0.742	-0.028	-0.063

Note:
Δ = Effluent – Influent, thus a positive Δ indicates an increase and a negative Δ indicates a decrease.

Table 88: Raw Nitrogen Data for BAM #3, A & B Columns, 22-minute EBCT

Approximate Flow Duration (hours)	Columns Run Date	Column Media #	Column Type	ERD Analyzed: Influent TN (mg/L as N)	ERD Analyzed: Effluent TN (mg/L as N)	ERD Analyzed: Influent NOx (mg/L as N)	ERD Analyzed: Effluent NOx (mg/L as N)	ERD Analyzed: Influent NH_3 (mg/L as N)	ERD Analyzed: Effluent NH_3 (mg/L as N)
2	9/27/2013	3	A	2.023	1.374	0.244	0.451	0.649	0.371
2	9/27/2013	3	B	2.023	1.468	0.244	0.493	0.649	0.361
2	10/4/2013	3	A	1.586	1.336	0.325	0.579	0.942	0.298
2	10/4/2013	3	B	1.586	1.315	0.325	0.517	0.942	0.317
2	10/18/2013	3	A	1.768	1.601	0.215	0.525	0.708	0.381
2	10/18/2013	3	B	1.768	1.427	0.215	0.420	0.708	0.403
2	10/25/2013	3	A	1.600	1.308	0.208	0.413	0.643	0.513
2	10/25/2013	3	B	1.600	1.193	0.208	0.338	0.643	0.538
2	11/1/2013	3	A	1.533	1.239	0.206	0.486	0.858	0.426
2	11/1/2013	3	B	1.533	1.213	0.206	0.426	0.858	0.492
2	11/8/2013	3	A	1.653	1.327	0.238	0.594	0.640	0.200
2	11/8/2013	3	B	1.653	1.305	0.238	0.524	0.640	0.267
2	11/15/2013	3	A	1.491	1.273	0.237	0.599	0.618	0.192
2	11/15/2013	3	B	1.491	1.339	0.237	0.562	0.618	0.298
2	11/22/2013	3	A	1.672	1.306	0.344	0.775	0.780	0.161
2	12/6/2013	3	A	1.548	1.259	0.256	0.593	0.482	0.108
2	12/11/2013	3	A	1.421	1.282	0.233	0.602	0.718	0.146
			median	1.6	1.308	0.237	0.524	0.649	0.317

Table 89: Calculated Nitrogen Data for BAM #3, A & B Columns, 22-minute EBCT

Columns Run Date	Column Type	Influent Organic Nitrogen (mg/L as N)	Effluent Organic Nitrogen (mg/L as N)	Δ Organic Nitrogen (mg/L as N)	Influent Inorganic Nitrogen (mg/L as N)	Effluent Inorganic Nitrogen (mg/L as N)	Δ Inorganic Nitrogen (mg/L as N)	Δ TN (mg/L as N)	% Removal of TN	Δ NOx (mg/L as N)	Δ NH_3 (mg/L as N)
9/27/2013	A	1.130	0.552	-0.578	0.893	0.822	-0.071	-0.649	32%	0.207	-0.278
9/27/2013	B	1.130	0.614	-0.516	0.893	0.854	-0.039	-0.555	27%	0.249	-0.288
10/4/2013	A	0.319	0.459	0.140	1.267	0.877	-0.390	-0.250	16%	0.254	-0.644
10/4/2013	B	0.319	0.481	0.162	1.267	0.834	-0.433	-0.271	17%	0.192	-0.625
10/18/2013	A	0.845	0.695	-0.150	0.923	0.906	-0.017	-0.167	9%	0.310	-0.327
10/18/2013	B	0.845	0.604	-0.241	0.923	0.823	-0.100	-0.341	19%	0.205	-0.305
10/25/2013	A	0.749	0.382	-0.367	0.851	0.926	0.075	-0.292	18%	0.205	-0.130
10/25/2013	B	0.749	0.317	-0.432	0.851	0.876	0.025	-0.407	25%	0.130	-0.105
11/1/2013	A	0.469	0.327	-0.142	1.064	0.912	-0.152	-0.294	19%	0.280	-0.432
11/1/2013	B	0.469	0.295	-0.174	1.064	0.918	-0.146	-0.320	21%	0.220	-0.366
11/8/2013	A	0.775	0.533	-0.242	0.878	0.794	-0.084	-0.326	20%	0.356	-0.440
11/8/2013	B	0.775	0.514	-0.261	0.878	0.791	-0.087	-0.348	21%	0.286	-0.373
11/15/2013	A	0.636	0.482	-0.154	0.855	0.791	-0.064	-0.218	15%	0.362	-0.426
11/15/2013	B	0.636	0.479	-0.157	0.855	0.860	0.005	-0.152	10%	0.325	-0.320
11/22/2013	A	0.548	0.370	-0.178	1.124	0.936	-0.188	-0.366	22%	0.431	-0.619
12/6/2013	A	0.810	0.558	-0.252	0.738	0.701	-0.037	-0.289	19%	0.337	-0.374
12/11/2013	A	0.470	0.534	0.064	0.951	0.748	-0.203	-0.139	10%	0.369	-0.572
	median	0.749	0.482	-0.178	0.893	0.854	-0.084	-0.294	19%	0.28	-0.373

Note:
Δ = Effluent – Influent, thus a positive Δ indicates an increase and a negative Δ indicates a decrease.

Table 90: Raw & Calculated Nitrogen Data for BAM #3, C Columns, 22-minute EBCT

Approximate Flow Duration (hours)	Columns Run Date	Column Media #	Column Type	ERD Analyzed: Influent NOx (mg/L as N)	ERD Analyzed: Effluent NOx (mg/L as N)	ERD Analyzed: Influent NH_3 (mg/L as N)	ERD Analyzed: Effluent NH_3 (mg/L as N)	Δ NH_3 (mg/L as N)	Δ NOx (mg/L as N)
2	9/27/2013	3	C	0.230	**0.176**	0.672	0.778	0.106	-0.054
2	10/4/2013	3	C	0.230	**0.174**	0.904	0.777	-0.127	-0.056
2	10/18/2013	3	C	0.204	**0.135**	0.679	0.796	0.117	-0.069
2	10/25/2013	3	C	0.196	**0.163**	0.658	0.754	0.096	-0.033
2	11/1/2013	3	C	0.208	**0.166**	0.899	0.929	0.030	-0.042
2	11/8/2013	3	C	0.226	**0.212**	0.644	0.622	-0.022	-0.014
2	11/15/2013	3	C	0.234	**0.203**	0.693	0.652	-0.041	-0.031
2	11/22/2013	3	C	0.271	**0.233**	0.845	0.658	-0.187	-0.038
2	12/6/2013	3	C	0.237	**0.209**	0.479	0.509	0.030	-0.028
2	12/11/2013	3	C	0.236	**0.184**	0.736	0.688	-0.048	-0.052
			Median	0.230	0.180	0.686	0.721	0.004	-0.040

Note:
Δ = Effluent – Influent, thus a positive Δ indicates an increase and a negative Δ indicates a decrease.

Table 91: Raw Nitrogen Data for BAM #3, A & B Columns, 220-minute EBCT

Approximate Flow Duration (hours)	Columns Run Date	Column Media #	Column Type	ERD Analyzed: Influent TN (mg/L as N)	ERD Analyzed: Effluent TN (mg/L as N)	ERD Analyzed: Influent NOx (mg/L as N)	ERD Analyzed: Effluent NOx (mg/L as N)	ERD Analyzed: Influent NH_3 (mg/L as N)	ERD Analyzed: Effluent NH_3 (mg/L as N)
24	9/24/2013	3	A	1.267	1.755	0.308	0.377	0.659	0.241
24	9/24/2013	3	B	1.267	0.923	0.308	0.165	0.659	0.324
24	10/1/2013	3	A	1.664	1.476	0.515	0.175	0.609	0.251
24	10/1/2013	3	B	1.664	0.570	0.515	0.081	0.609	0.175
24	10/8/2013	3	A	1.444	0.755	0.329	0.289	0.735	0.034
24	10/8/2013	3	B	1.444	0.628	0.329	0.158	0.735	0.085
24	10/15/2013	3	A	1.781	1.097	0.233	0.027	0.815	0.574
24	10/15/2013	3	B	1.781	1.120	0.233	0.053	0.815	0.648
24	10/29/2013	3	A	1.623	1.371	0.258	0.330	0.793	0.410
24	10/29/2013	3	B	1.623	1.244	0.258	0.298	0.793	0.375
24	11/5/2013	3	A	1.594	0.880	0.261	0.278	0.660	0.104
24	11/5/2013	3	B	1.594	0.778	0.261	0.152	0.660	0.066
24	11/12/2013	3	A	1.747	1.196	0.348	0.581	0.763	0.075
24	11/12/2013	3	B	1.747	1.093	0.348	0.494	0.763	0.149
24	11/19/2013	3	A	1.528	1.072	0.330	0.507	0.571	0.003
24	12/3/2013	3	A	0.834	0.468	0.261	0.450	0.492	0.003
24	12/12/2013	3	A	1.142	1.145	0.327	0.705	0.757	0.010
			median	1.594	1.093	0.308	0.289	0.735	0.149

Table 92: Calculated Nitrogen Data for BAM #3, A & B Columns, 220-minute EBCT

Columns Run Date	Column Type	Influent Organic Nitrogen (mg/L as N)	Effluent Organic Nitrogen (mg/L as N)	Δ Organic Nitrogen (mg/L as N)	Influent Inorganic Nitrogen (mg/L as N)	Effluent Inorganic Nitrogen (mg/L as N)	Δ Inorganic Nitrogen (mg/L as N)	Δ TN (mg/L as N)	% Removal of TN	Δ NOx (mg/L as N)	Δ NH_3 (mg/L as N)
9/24/2013	A	0.300	1.137	0.837	0.967	0.618	-0.349	0.488	-39%	0.069	-0.418
9/24/2013	B	0.300	0.434	0.134	0.967	0.489	-0.478	-0.344	27%	-0.143	-0.335
10/1/2013	A	0.540	1.050	0.510	1.124	0.426	-0.698	-0.188	11%	-0.340	-0.358
10/1/2013	B	0.540	0.314	-0.226	1.124	0.256	-0.868	-1.094	66%	-0.434	-0.434
10/8/2013	A	0.380	0.432	0.052	1.064	0.323	-0.741	-0.689	48%	-0.040	-0.701
10/8/2013	B	0.380	0.385	0.005	1.064	0.243	-0.821	-0.816	57%	-0.171	-0.650
10/15/2013	A	0.733	0.496	-0.237	1.048	0.601	-0.447	-0.684	38%	-0.206	-0.241
10/15/2013	B	0.733	0.419	-0.314	1.048	0.701	-0.347	-0.661	37%	-0.180	-0.167
10/29/2013	A	0.572	0.631	0.059	1.051	0.740	-0.311	-0.252	16%	0.072	-0.383
10/29/2013	B	0.572	0.571	-0.001	1.051	0.673	-0.378	-0.379	23%	0.040	-0.418
11/5/2013	A	0.673	0.498	-0.175	0.921	0.382	-0.539	-0.714	45%	0.017	-0.556
11/5/2013	B	0.673	0.560	-0.113	0.921	0.218	-0.703	-0.816	51%	-0.109	-0.594
11/12/2013	A	0.636	0.540	-0.096	1.111	0.656	-0.455	-0.551	32%	0.233	-0.688
11/12/2013	B	0.636	0.450	-0.186	1.111	0.643	-0.468	-0.654	37%	0.146	-0.614
11/19/2013	A	0.627	0.562	-0.065	0.901	0.510	-0.391	-0.456	30%	0.177	-0.568
12/3/2013	A	0.081	0.015	-0.066	0.753	0.453	-0.300	-0.366	44%	0.189	-0.489
12/12/2013	A	0.058	0.430	0.372	1.084	0.715	-0.369	0.003	0%	0.378	-0.747
	median	0.572	0.496	-0.065	1.051	0.510	-0.455	-0.551	37%	0.017	-0.489

Note:
Δ = Effluent – Influent, thus a positive Δ indicates an increase and a negative Δ indicates a decrease.

Table 93: Raw & Calculated Nitrogen Data for BAM #3, C Columns, 220-minute EBCT

Approximate Flow Duration (hours)	Columns Run Date	Column Media #	Column Type	ERD Analyzed: Influent NOx (mg/L as N)	ERD Analyzed: Effluent NOx (mg/L as N)	ERD Analyzed: Influent NH_3 (mg/L as N)	ERD Analyzed: Effluent NH_3 (mg/L as N)	Δ NH_3 (mg/L as N)	Δ NOx (mg/L as N)
24	9/24/2013	3	C	0.251	0.044	0.770	1.192	0.422	-0.207
24	10/1/2013	3	C	0.280	0.017	0.824	0.821	-0.003	-0.263
24	10/8/2013	3	C	0.247	0.019	0.719	0.646	-0.073	-0.228
24	10/15/2013	3	C	0.229	0.012	0.792	1.209	0.417	-0.217
24	10/22/2013	3	C	0.264	0.005	0.530	0.373	-0.157	-0.259
24	10/29/2013	3	C	0.229	0.033	0.956	1.045	0.089	-0.196
24	11/5/2013	3	C	0.224	0.024	0.760	0.484	-0.276	-0.200
24	11/12/2013	3	C	0.270	0.069	0.898	0.824	-0.074	-0.201
24	11/19/2013	3	C	0.228	0.038	0.729	0.453	-0.276	-0.190
24	12/3/2013	3	C	0.232	0.043	0.608	0.611	0.003	-0.189
24	12/12/2013	3	C	0.244	0.153	0.786	0.661	-0.125	-0.091
			Median	0.244	0.033	0.770	0.661	-0.073	-0.201

Note:
Δ = Effluent – Influent, thus a positive Δ indicates an increase and a negative Δ indicates a decrease.

APPENDIX R
PHOSPHORUS

Analysis of phosphorus data was only conducted on data from the A & B Columns. Only phosphorus data for the B Columns prior to antibiotics being added (pre 11/19/2013) was used in the phosphorus analysis.

Table 94: SRP for BAM #1, 22-minute EBCT

Columns Run Date	Approximate Flow Duration (hours)	Column Media #	Column Type	ERD Analyzed: Influent SRP (mg/L as P)	ERD Analyzed: Effluent SRP (mg/L as P)
5/1/2013	2	1	A	0.206	0.087
5/1/2013	2	1	B	0.206	0.123
6/6/2013	2	1	A	0.236	0.065
6/6/2013	2	1	B	0.236	0.119
6/13/2013	2	1	A	0.18	0.062
6/13/2013	2	1	B	0.18	0.062
6/20/2013	2	1	A	0.204	0.071
6/20/2013	2	1	B	0.204	0.066
7/2/2013	2	1	A	0.211	0.078
7/2/2013	2	1	B	0.211	0.057
9/27/2013	2	1	A	0.179	0.068
9/27/2013	2	1	B	0.179	0.078
10/4/2013	2	1	A	0.149	0.059
10/4/2013	2	1	B	0.149	0.058
10/18/2013	2	1	A	0.189	0.097
10/18/2013	2	1	B	0.189	0.101
10/25/2013	2	1	A	0.182	0.089
10/25/2013	2	1	B	0.182	0.094
11/1/2013	2	1	A	0.164	0.078
11/1/2013	2	1	B	0.164	0.086
11/8/2013	2	1	A	0.203	0.092
11/8/2013	2	1	B	0.203	0.078
11/15/2013	2	1	A	0.147	0.099
11/22/2013	2	1	A	0.163	0.096
12/6/2013	2	1	A	0.188	0.092
12/11/2013	2	1	A	0.177	0.095
			MEDIAN	0.185	0.082

Table 95: SRP for BAM #1, 220-minute EBCT

Columns Run Date	Approximate Flow Duration (hours)	Column Media #	Column Type	ERD Analyzed: Influent SRP (mg/L as P)	ERD Analyzed: Effluent SRP (mg/L as P)
6/25/2013	24	1	A	0.173	0.02
6/25/2013	24	1	B	0.173	0.03
9/24/2013	24	1	A	0.19	0.026
9/24/2013	24	1	B	0.19	0.026
10/1/2013	24	1	A	0.132	0.079
10/1/2013	24	1	B	0.132	0.055
10/8/2013	24	1	A	0.213	0.128
10/8/2013	24	1	B	0.213	0.103
10/15/2013	24	1	A	0.163	0.109
10/15/2013	24	1	B	0.163	0.095
10/22/2013	24	1	A	0.164	0.03
10/22/2013	24	1	B	0.164	0.047
10/29/2013	24	1	A	0.185	0.053
10/29/2013	24	1	B	0.185	0.066
11/5/2013	24	1	A	0.184	0.062
11/5/2013	24	1	B	0.184	0.04
11/12/2013	24	1	A	0.192	0.059
11/12/2013	24	1	B	0.192	0.061
11/19/2013	24	1	A	0.158	0.033
12/3/2013	24	1	A	0.175	0.018
12/12/2013	24	1	A	0.174	0.086
			MEDIAN	0.175	0.055

Table 96: SRP for BAM #2, 22-minute EBCT

Columns Run Date	Approximate Flow Duration (hours)	Column Media #	Column Type	ERD Analyzed: Influent SRP (mg/L as P)	ERD Analyzed: Effluent SRP (mg/L as P)
5/1/2013	2	2	A	0.206	0.052
5/1/2013	2	2	B	0.206	0.064
6/6/2013	2	2	A	0.236	0.075
6/6/2013	2	2	B	0.236	0.084
6/13/2013	2	2	A	0.18	0.085
6/13/2013	2	2	B	0.18	0.114
6/20/2013	2	2	A	0.204	0.098
6/20/2013	2	2	B	0.204	0.153
7/2/2013	2	2	A	0.211	0.122
7/2/2013	2	2	B	0.211	0.149
9/27/2013	2	2	A	0.179	0.144
9/27/2013	2	2	B	0.179	0.143
10/4/2013	2	2	A	0.149	0.126
10/4/2013	2	2	B	0.149	0.128
10/18/2013	2	2	A	0.189	0.142
10/18/2013	2	2	B	0.189	0.137
10/25/2013	2	2	A	0.182	0.151
10/25/2013	2	2	B	0.182	0.142
11/1/2013	2	2	A	0.164	0.139
11/1/2013	2	2	B	0.164	0.13
11/8/2013	2	2	A	0.203	0.164
11/8/2013	2	2	B	0.203	0.149
11/15/2013	2	2	A	0.147	0.13
11/15/2013	2	2	B	0.147	0.146
11/22/2013	2	2	A	0.163	0.133
12/6/2013	2	2	A	0.188	0.129
12/11/2013	2	2	A	0.177	0.153
			MEDIAN	0.182	0.133

Table 97: SRP for BAM #2, 220-minute EBCT

Columns Run Date	Approximate Flow Duration (hours)	Column Media #	Column Type	ERD Analyzed: Influent SRP (mg/L as P)	ERD Analyzed: Effluent SRP (mg/L as P)
6/25/2013	24	2	A	0.173	0.078
6/25/2013	24	2	B	0.173	0.096
9/24/2013	24	2	A	0.19	0.131
9/24/2013	24	2	B	0.19	0.145
10/1/2013	24	2	A	0.132	0.123
10/1/2013	24	2	B	0.132	0.116
10/8/2013	24	2	A	0.213	0.161
10/8/2013	24	2	B	0.213	0.172
10/15/2013	24	2	A	0.163	0.12
10/15/2013	24	2	B	0.163	0.11
10/22/2013	24	2	A	0.164	0.073
10/22/2013	24	2	B	0.164	0.087
10/29/2013	24	2	A	0.185	0.107
10/29/2013	24	2	B	0.185	0.105
11/5/2013	24	2	A	0.184	0.087
11/5/2013	24	2	B	0.184	0.081
11/12/2013	24	2	A	0.192	0.148
11/12/2013	24	2	B	0.192	0.091
11/19/2013	24	2	A	0.158	0.076
12/3/2013	24	2	A	0.175	0.095
12/12/2013	24	2	A	0.174	0.146
			MEDIAN	0.175	0.107

Table 98: SRP for BAM #3, 22-minute EBCT

Columns Run Date	Approximate Flow Duration (hours)	Column Media #	Column Type	ERD Analyzed: Influent SRP (mg/L as P)	ERD Analyzed: Effluent SRP (mg/L as P)
5/1/2013	2	3	A	0.206	0.122
5/1/2013	2	3	B	0.206	0.104
6/6/2013	2	3	A	0.236	0.1
6/6/2013	2	3	B	0.236	0.108
6/13/2013	2	3	A	0.18	0.106
6/13/2013	2	3	B	0.18	0.113
6/20/2013	2	3	A	0.204	0.124
6/20/2013	2	3	B	0.204	0.126
7/2/2013	2	3	A	0.211	0.019
7/2/2013	2	3	B	0.211	0.095
9/27/2013	2	3	A	0.179	0.119
9/27/2013	2	3	B	0.179	0.101
10/4/2013	2	3	A	0.149	0.095
10/4/2013	2	3	B	0.149	0.09
10/18/2013	2	3	A	0.189	0.133
10/18/2013	2	3	B	0.189	0.127
10/25/2013	2	3	A	0.182	0.132
10/25/2013	2	3	B	0.182	0.109
11/1/2013	2	3	A	0.164	0.122
11/1/2013	2	3	B	0.164	0.124
11/8/2013	2	3	A	0.203	0.114
11/8/2013	2	3	B	0.203	0.103
11/15/2013	2	3	A	0.147	0.111
11/15/2013	2	3	B	0.147	0.11
11/22/2013	2	3	A	0.163	0.11
12/6/2013	2	3	A	0.188	0.019
12/11/2013	2	3	A	0.177	0.114
			MEDIAN	0.182	0.110

Table 99: SRP for BAM #3, 220-minute EBCT

Columns Run Date	Approximate Flow Duration (hours)	Column Media #	Column Type	ERD Analyzed: Influent SRP (mg/L as P)	ERD Analyzed: Effluent SRP (mg/L as P)
6/25/2013	24	3	A	0.173	0.136
6/25/2013	24	3	B	0.173	0.131
9/24/2013	24	3	A	0.19	0.136
9/24/2013	24	3	B	0.19	0.14
10/1/2013	24	3	A	0.132	0.139
10/1/2013	24	3	B	0.132	0.142
10/8/2013	24	3	A	0.213	0.124
10/8/2013	24	3	B	0.213	0.205
10/15/2013	24	3	A	0.163	0.186
10/15/2013	24	3	B	0.163	0.264
10/22/2013	24	3	A	0.164	0.089
10/22/2013	24	3	B	0.164	0.117
10/29/2013	24	3	A	0.185	0.142
10/29/2013	24	3	B	0.185	0.167
11/5/2013	24	3	A	0.184	0.102
11/5/2013	24	3	B	0.184	0.136
11/12/2013	24	3	A	0.192	0.133
11/12/2013	24	3	B	0.192	0.146
11/19/2013	24	3	A	0.158	0.077
12/3/2013	24	3	A	0.175	0.095
12/12/2013	24	3	A	0.174	0.124
			MEDIAN	0.175	0.136

Table 100: Total Phosphorus for BAM #1, 22-minute EBCT

Columns Run Date	Approximate Flow Duration (hours)	Column Media #	Column Type	ERD Analyzed: Influent Total P (mg/L as P)	ERD Analyzed: Effluent Total P (mg/L as P)
5/1/2013	2	1	A	0.221	0.097
5/1/2013	2	1	B	0.221	0.129
6/6/2013	2	1	A	0.241	0.077
6/6/2013	2	1	B	0.241	0.122
6/13/2013	2	1	A	0.189	0.071
6/13/2013	2	1	B	0.189	0.082
6/20/2013	2	1	A	0.211	0.107
6/20/2013	2	1	B	0.211	0.105
7/2/2013	2	1	A	0.406	0.209
7/2/2013	2	1	B	0.406	0.22
7/31/2013	2	1	A	0.248	0.098
7/31/2013	2	1	B	0.248	0.111
8/7/2013	2	1	A	0.161	0.082
8/7/2013	2	1	B	0.161	0.095
8/15/2013	2	1	A	0.152	0.126
8/15/2013	2	1	B	0.152	0.125
8/30/2013	2	1	A	0.256	0.215
8/30/2013	2	1	B	0.256	0.299
9/27/2013	2	1	A	0.276	0.121
9/27/2013	2	1	B	0.276	0.138
10/4/2013	2	1	A	0.25	0.084
10/4/2013	2	1	B	0.25	0.084
10/18/2013	2	1	A	0.245	0.11
10/18/2013	2	1	B	0.245	0.124
10/25/2013	2	1	A	0.233	0.121
10/25/2013	2	1	B	0.233	0.126
11/1/2013	2	1	A	0.245	0.109
11/1/2013	2	1	B	0.245	0.116
11/8/2013	2	1	A	0.221	0.115
11/8/2013	2	1	B	0.221	0.104
11/15/2013	2	1	A	0.173	0.136
11/22/2013	2	1	A	0.266	0.121
12/6/2013	2	1	A	0.166	0.158
12/11/2013	2	1	A	0.186	0.104
			MEDIAN	0.237	0.1155

Table 101: Total Phosphorus for BAM #1, 220-minute EBCT

Columns Run Date	Approximate Flow Duration (hours)	Column Media #	Column Type	ERD Analyzed: Influent Total P (mg/L as P)	ERD Analyzed: Effluent Total P (mg/L as P)
6/25/2013	24	1	A	0.191	0.106
6/25/2013	24	1	B	0.191	0.137
7/11/2013	24	1	A	0.206	0.118
7/11/2013	24	1	B	0.206	0.13
7/24/2013	24	1	A	0.447	0.27
7/24/2013	24	1	B	0.447	0.315
8/1/2013	24	1	A	0.017	0.111
8/1/2013	24	1	B	0.017	0.078
8/5/2013	24	1	A	0.154	0.081
8/5/2013	24	1	B	0.154	0.081
8/13/2013	24	1	A	0.148	0.115
8/13/2013	24	1	B	0.148	0.112
8/27/2013	24	1	A	0.469	0.273
8/27/2013	24	1	B	0.469	0.397
9/3/2013	24	1	A	0.252	0.149
9/3/2013	24	1	B	0.252	0.12
9/24/2013	24	1	A	0.209	0.262
9/24/2013	24	1	B	0.209	7.854
10/1/2013	24	1	A	0.209	0.161
10/1/2013	24	1	B	0.209	0.207
10/8/2013	24	1	A	0.226	0.145
10/8/2013	24	1	B	0.226	0.106
10/15/2013	24	1	A	0.315	0.231
10/15/2013	24	1	B	0.315	0.45
10/22/2013	24	1	A	0.203	0.116
10/22/2013	24	1	B	0.203	0.151
10/29/2013	24	1	A	0.198	0.099
10/29/2013	24	1	B	0.198	0.101
11/5/2013	24	1	A	0.205	0.116
11/5/2013	24	1	B	0.205	0.114
11/12/2013	24	1	A	0.22	0.112
11/12/2013	24	1	B	0.22	0.116
11/19/2013	24	1	A	0.182	0.078
12/3/2013	24	1	A	0.176	0.075
12/12/2013	24	1	A	0.196	0.089
			MEDIAN	0.206	0.116

Table 102: Total Phosphorus for BAM #2, 22-minute EBCT

Columns Run Date	Approximate Flow Duration (hours)	Column Media #	Column Type	ERD Analyzed: Influent Total P (mg/L as P)	ERD Analyzed: Effluent Total P (mg/L as P)
5/1/2013	2	2	A	0.221	0.086
5/1/2013	2	2	B	0.221	0.197
6/6/2013	2	2	A	0.241	0.078
6/6/2013	2	2	B	0.241	0.165
6/13/2013	2	2	A	0.189	0.09
6/13/2013	2	2	B	0.189	0.183
6/20/2013	2	2	A	0.211	0.107
6/20/2013	2	2	B	0.211	0.317
7/2/2013	2	2	A	0.406	0.207
7/2/2013	2	2	B	0.406	0.298
7/31/2013	2	2	A	0.248	0.191
7/31/2013	2	2	B	0.248	0.232
8/7/2013	2	2	A	0.161	0.175
8/7/2013	2	2	B	0.161	0.2
8/15/2013	2	2	A	0.152	0.123
8/15/2013	2	2	B	0.152	0.194
8/30/2013	2	2	A	0.256	0.18
8/30/2013	2	2	B	0.256	0.236
9/27/2013	2	2	A	0.276	0.167
9/27/2013	2	2	B	0.276	0.296
10/4/2013	2	2	A	0.25	0.175
10/4/2013	2	2	B	0.25	0.273
10/18/2013	2	2	A	0.245	0.161
10/18/2013	2	2	B	0.245	0.171
10/25/2013	2	2	A	0.233	0.195
10/25/2013	2	2	B	0.233	0.172
11/1/2013	2	2	A	0.245	0.172
11/1/2013	2	2	B	0.245	0.196
11/8/2013	2	2	A	0.221	0.213
11/8/2013	2	2	B	0.221	0.175
11/15/2013	2	2	A	0.173	0.161
11/15/2013	2	2	B	0.173	0.172
11/22/2013	2	2	A	0.266	0.462
12/6/2013	2	2	A	0.166	0.174
12/11/2013	2	2	A	0.186	0.353
			MEDIAN	0.233	0.180

Table 103: Total Phosphorus for BAM #2, 220-minute EBCT

Columns Run Date	Approximate Flow Duration (hours)	Column Media #	Column Type	ERD Analyzed: Influent Total P (mg/L as P)	ERD Analyzed: Effluent Total P (mg/L as P)
6/25/2013	24	2	A	0.191	0.099
6/25/2013	24	2	B	0.191	0.126
7/11/2013	24	2	A	0.206	0.103
7/11/2013	24	2	B	0.206	0.125
7/24/2013	24	2	A	0.447	0.27
7/24/2013	24	2	B	0.447	0.406
8/1/2013	24	2	A	0.017	0.059
8/1/2013	24	2	B	0.017	0.087
8/5/2013	24	2	A	0.154	0.074
8/5/2013	24	2	B	0.154	0.098
8/13/2013	24	2	A	0.148	0.108
8/13/2013	24	2	B	0.148	0.115
8/27/2013	24	2	A	0.469	0.148
8/27/2013	24	2	B	0.469	0.135
9/3/2013	24	2	A	0.252	0.237
9/3/2013	24	2	B	0.252	0.194
9/24/2013	24	2	A	0.209	0.271
9/24/2013	24	2	B	0.209	0.253
10/1/2013	24	2	A	0.209	0.15
10/1/2013	24	2	B	0.209	0.142
10/8/2013	24	2	A	0.226	0.18
10/8/2013	24	2	B	0.226	0.181
10/15/2013	24	2	A	0.315	0.214
10/15/2013	24	2	B	0.315	0.303
10/22/2013	24	2	A	0.203	0.097
10/22/2013	24	2	B	0.203	0.161
10/29/2013	24	2	A	0.198	0.113
10/29/2013	24	2	B	0.198	0.143
11/5/2013	24	2	A	0.205	0.113
11/5/2013	24	2	B	0.205	0.131
11/12/2013	24	2	A	0.22	0.222
11/12/2013	24	2	B	0.22	0.145
11/19/2013	24	2	A	0.182	0.116
12/3/2013	24	2	A	0.176	0.11
12/12/2013	24	2	A	0.196	0.223
			MEDIAN	0.206	0.142

Table 104: Total Phosphorus for BAM #3, 22-minute EBCT

Columns Run Date	Approximate Flow Duration (hours)	Column Media #	Column Type	ERD Analyzed: Influent Total P (mg/L as P)	ERD Analyzed: Effluent Total P (mg/L as P)
5/1/2013	2	3	A	0.221	0.129
5/1/2013	2	3	B	0.221	0.237
6/6/2013	2	3	A	0.241	0.103
6/6/2013	2	3	B	0.241	0.109
6/13/2013	2	3	A	0.189	0.123
6/13/2013	2	3	B	0.189	0.124
6/20/2013	2	3	A	0.211	0.126
6/20/2013	2	3	B	0.211	0.13
7/2/2013	2	3	A	0.406	0.136
7/2/2013	2	3	B	0.406	0.131
7/31/2013	2	3	A	0.248	0.202
7/31/2013	2	3	B	0.248	0.17
8/7/2013	2	3	A	0.161	0.191
8/7/2013	2	3	B	0.161	0.115
8/15/2013	2	3	A	0.152	0.156
8/15/2013	2	3	B	0.152	0.111
8/30/2013	2	3	A	0.256	0.199
8/30/2013	2	3	B	0.256	na
9/27/2013	2	3	A	0.276	0.137
9/27/2013	2	3	B	0.276	0.118
10/4/2013	2	3	A	0.25	0.103
10/4/2013	2	3	B	0.25	0.103
10/18/2013	2	3	A	0.245	0.168
10/18/2013	2	3	B	0.245	0.142
10/25/2013	2	3	A	0.233	0.153
10/25/2013	2	3	B	0.233	0.142
11/1/2013	2	3	A	0.245	0.152
11/1/2013	2	3	B	0.245	0.128
11/8/2013	2	3	A	0.221	0.122
11/8/2013	2	3	B	0.221	0.113
11/15/2013	2	3	A	0.173	0.148
11/15/2013	2	3	B	0.173	0.13
11/22/2013	2	3	A	0.266	0.135
12/6/2013	2	3	A	0.166	0.126
12/11/2013	2	3	A	0.186	0.121
			MEDIAN	0.233	0.130

Table 105: Total Phosphorus for BAM #3, 220-minute EBCT

Columns Run Date	Approximate Flow Duration (hours)	Column Media #	Column Type	ERD Analyzed: Influent Total P (mg/L as P)	ERD Analyzed: Effluent Total P (mg/L as P)
6/25/2013	24	3	A	0.191	0.178
6/25/2013	24	3	B	0.191	0.177
7/11/2013	24	3	A	0.206	0.171
7/11/2013	24	3	B	0.206	0.19
7/24/2013	24	3	A	0.447	0.419
7/24/2013	24	3	B	0.447	0.277
8/1/2013	24	3	A	0.017	0.183
8/1/2013	24	3	B	0.017	0.144
8/5/2013	24	3	A	0.154	0.179
8/5/2013	24	3	B	0.154	0.149
8/13/2013	24	3	A	0.148	0.154
8/13/2013	24	3	B	0.148	0.16
8/27/2013	24	3	A	0.469	0.213
8/27/2013	24	3	B	0.469	0.203
9/3/2013	24	3	A	0.252	0.197
9/3/2013	24	3	B	0.252	0.225
9/24/2013	24	3	A	0.209	0.207
9/24/2013	24	3	B	0.209	0.23
10/1/2013	24	3	A	0.209	0.184
10/1/2013	24	3	B	0.209	0.188
10/8/2013	24	3	A	0.226	0.185
10/8/2013	24	3	B	0.226	0.235
10/15/2013	24	3	A	0.315	0.297
10/15/2013	24	3	B	0.315	0.419
10/22/2013	24	3	A	0.203	0.144
10/22/2013	24	3	B	0.203	0.158
10/29/2013	24	3	A	0.198	0.139
10/29/2013	24	3	B	0.198	0.172
11/5/2013	24	3	A	0.205	0.177
11/5/2013	24	3	B	0.205	0.155
11/12/2013	24	3	A	0.22	0.166
11/12/2013	24	3	B	0.22	0.181
11/19/2013	24	3	A	0.182	0.119
12/3/2013	24	3	A	0.176	0.115
12/12/2013	24	3	A	0.196	0.142
			MEDIAN	0.206	0.179

REFERENCES

1. McCarthy, D.T., *A traditional first flush assessment of E. coli in urban stormwater runoff.* Water Science and Technology, 2009. **60**(11): p. 2749-2757.

2. U.S. EPA, *Preliminary Data Summary of Urban Storm Water Best Management Practices*. 1999, United States Environmental Protection Agency.

3. U.S. EPA, *Guidelines for Water Reuse*. 2012: United States Environmental Protection Agency.

4. Kucera, J., *Biofouling of Polyamide Membranes: Fouling Mechanisms, Current Mitigation and Cleaning Strategies, and Future Prospects.* Membranes, 2019. **9**(9): p. 111.

5. Cripps, S.J., *Serial particle size fractionation and characterisation of an aquacultural effluent.* Aquaculture, 1995. **133**(3-4): p. 323-339.

6. Wanielista, M. and E. Hulstein. *Stormwater Irrigation for Saint Augustine Grass: Summer ET and Nitrogen Data on the UCF Campus*. in *1st Annual Stormwater Management Research Symposium Proceedings*. 2004. Orlando, FL: University of Central Florida Stormwater Management Academy.

7. U.S. EPA. *Drinking Water Contaminants*. Water 2011 September 30, 2011 [cited 2011 October 2, 2011]; Available from: http://water.epa.gov/drink/contaminants/index.cfm#List.

8. Ward, M.H., T.M. deKok, P. Levallois, J. Brender, G. Gulis, B.T. Nolan, and J. VanDerslice, *Workgroup Report: Drinking-Water Nitrate and Health-Recent Findings and Research Needs.* Environmental Health Perspectives, 2005. **113**(11): p. 1607-1614.

9. U.S. EPA. *Glossary*. Water Quality Criteria for Nitrogen and Phosphorus Pollution 2011 September 29, 2011 [cited 2011 October 2, 2011]; Available from: http://water.epa.gov/scitech/swguidance/standards/criteria/nutrients/glossary.cfm.

10. Wenner, E., D. Sanger, S. Upchurch, and M. Thompson, *Water Quality Module: Eutrophication*, in *Characterization of the Ashepoo-Combahee-Edisto Basin, South Carolina*. 2000, National Oceanic and Atmospheric Administration.

11. U.S. EPA. *Hypoxia, Anoxia, & Harmful Algal Blooms*. Water Quality Criteria for Nitrogen and Phosphorus Pollution 2011 September 29, 2011 [cited 2011 October 2, 2011]; Available from: http://water.epa.gov/scitech/swguidance/standards/criteria/nutrients/habs.cfm.

12. Landsberg, J.H. and S.S. Shumway. *Harmful Algal Blooms and Their Effects on Marine and Estuarine Animals*. in *Third International Symposium on Aquatic Animal Health*. 1998. Baltimore, Maryland.

13. U.S. EPA. *Effects of Nitrogen and Phosphorus Pollution*. Water Quality Criteria for Nitrogen and Phosphorus Pollution 2011 September 29, 2011 [cited 2011 October 2, 2011]; Available from: http://water.epa.gov/scitech/swguidance/standards/criteria/nutrients/effects.cfm.

14. Pitt, R., A. Maestre, and J. Clary, *The National Stormwater Quality Database (NSQD, version 4.02)*. 2015, University of Alabama: Tuscaloosa.

15. Metcalf & Eddy, *Analysis and Selection of Wastewater Flowrates and Constituents Loadings*, in *Wastewater Engineering: Treatment and Reuse*. 2003, McGraw-Hill: New York. p. 153-213.

16. Shoemaker, L., M. Lahlou, A. Doll, and P. Cazenas, *Stormwater best management practices in an ultra-urban setting: selection and monitoring*. 2002, US Department of Transportation, Federal Highway Administration: Washington, D.C.

17. Mangani, G., A. Berloni, F. Bellucci, F. Tatano, and M. Maione, *Evaluation of the Pollutant Content in Road Runoff First Flush Waters.* Water, Air, Soil Pollution, 2005. **160**(1): p. 213-228.

18. Pitt, R., A. Maestre, and R. Morquecho, *The National Stormwater Quality Database (NSQD, version 1.1)*. 2004, University of Alabama: Tuscaloosa.

19. Harper, H.H. *New Updates to the Florida Runoff Concentration (emc) Database*. in *Florida Stormwater Association*. 2011. Tampa.

20. NCHRP, *Guidelines for Evaluating and Selecting Modifications to Existing Roadway Drainage Infrastructure to Improve Water Quality in Ultra-Urban Areas*. 2012, Transportation Research Board: Washington, D.C.

21. U.S. EPA, *Storm Water Technology Fact Sheet Sand Filters*. 1999, United States Environmental Protection Agency: Washington, D.C.

22. Caltrans, *Highway 267 Filter Fabric Sand Trap Pilot Study 2004-2005 Interim Report*. 2006, California Department of Transportation: Division of Environmental Analysis: Sacramento, California.

23. City of Austin Texas, *Design Guidelines for Water Quality Controls*, in *City of Austin, Texas Environmental Criteria Manual*. 2013, American Legal Publishing Corporation: Cincinnati, Ohio.

24. MASSHighway, *Storm Water Handbook For Highways and Bridges*. 2004, Massachusetts Highway Department: Boston, MA.

25. Chang, N.-B., F. Hossain, and M. Wanielista, *Filter Media for Nutrient Removal in Natural Systems and Built Environments: I—Previous Trends and Perspectives.* Environmental Engineering Science, 2010. **27**(9): p. 689-706.

26. Woelkers, D., B. Pitt, and S. Clark. *Stormwater Treatment Filtration as a Stormwater Control*. in *StormCon*. 2006. Denver, CO.

27. Hardin, M., M. Wanielista, and M. Chopra, *A Mass Balance Model for Designing Green Roof Systems that Incorporate a Cistern for Re-Use.* Water, 2012. **4**(4): p. 914-931.

28. Ryan, P., M. Wanielista, and N.-B. Chang, *Nutrient Reduction in Stormwater Pond Discharge Using a Chamber Upflow Filter and Skimmer (CUFS).* Water, Soil, and Air Pollution, 2010. **208**(1-4): p. 385-399.

29. WSDOT, *Washington State Department of Transportation Highway Runoff Manual, M 31-16.01*. 2008, Olympia, WA: Washington State Department of Transportation.

30. Ma, J., K. Tracy, and J. Lenhart. *Phosphorus Removal in Urban Runoff Using Adsorptive Filtration Media*. in *StormCon*. 2009. Anaheim, CA.

31. Kim, H., E.A. Seagren, and A.P. Davis, *Engineered Bioretention for Removal of Nitrate from Stormwater Runoff.* Water Environment Federation, 2003. **75**(4): p. 355-367.

32. O'Reilly, A.M., M.P. Wanielista, N.-B. Chang, Z. Xuan, and W.G. Harris, *Nutrient removal using biosorption activated media: Preliminary biogeochemical assessment of an innovative stormwater infiltration basin.* Science of the Total Environment, 2012. **432**: p. 227-242.

33. Milesi, C., S. de Ridder, D. DeLeon, and H. Wachter. *A Comparison of Two Media Filtration Bmp Treatments for the Removal of PAHs and Phthalates from Roadway Runoff*. in *StormCon*. 2006. Denver, CO.

34. Pitt, R. and S.E. Clark, *Evaluation of Biofiltration Media for Engineered Natural Treatment Systems*. 2010, Geosyntec Consultants: Santa Barbara, CA.

35. Hood, A.C., *Evaluation of Biosorption Activated Media Under Roadside Swales for Stormwater Quality Improvement & Harvesting*, in *Civil, Environmental, and Construction Engineering*. 2012, University of Central Florida: Orlando, FL.

36. Chang, N.-B., *Making a Progress to Speed up the Nitrification and Denitrification Processes in Novel Biosorption Activated Media: Can Archaea be in Concert with Anammox?* BioProcessing & Biotechniques, 2011. **1**(2).

37. Chojnacka, K., *Biosorption and bioaccumulation – the prospects for practical applications.* Environment International, 2010. **36**(3): p. 299-307.

38. Metcalf & Eddy, *Fundamentals of Biological Treatment*, in *Wastewater Engineering: Treatment and Reuse*. 2003, McGraw-Hill: New York. p. 545-657.

39. Geets, J., M.d. Cooman, L. Wittebolle, K. Heylen, B. Vanparys, P.D. Vos, W. Verstraete, and N. Boon, *Real-time PCR assay for the simultaneous quantification of nitrifying and denitrifying bacteria in activated sludge.* Environmental Biotechnology, 2007. **75**(1): p. 211-221.

40. NOAA. *Summertime Dissolved Oxygen Levels—What Do They Mean for Fish…and Fishermen?* Chesapeake Bay Interpretive Buoy System 2018 [cited 2018 September 23, 2018]; Available from: https://buoybay.noaa.gov/news/summertime-dissolved-oxygen-levels-what-do-they-mean-for-fish-and-fishermen.

41. Strecker, E., D. Bodine, M. Leisenring, W. Huber, J. Sansalone, D. Pankani, J. Heaney, M. Quigley, and A. Thayumanavan, *Critical Assessment of Stormwater Treatment and Control Selection Issues*. 2005, Alexandria, VA: Water Environment Research Foundation.

42. Helmer, C., C. Tromm, A. Hippen, K.-H. Rosenwinkel, C. Seyfried, and S. Kunst, *Single stage biological nitrogen removal by nitritation and anaerobic ammonium oxidation in biofilm systems.* Water Science and Technology, 2001. **43**(1): p. 311-320.

43. Motlagh, A.M. and R.K. Goel, *Sustainability of Activated Sludge Processes*, in *Water Reclamation and Sustainability*, S. Ahuja, Editor. 2014, Elsevier: San Diego, CA. p. 391-414.

44. Op den Camp, H.J.M., M.S.M. Jetten, and M. Strous, *Anammox*, in *Biology of the Nitrogen Cycle*, H. Bothe, S.J. Ferguson, and W.E. Newton, Editors. 2007, Elsevier B.V. p. 245-262.

45. Kuenen, J.G., *Anammox bacteria: from discovery to application.* Nature Reviews Microbiology, 2008. **6**: p. 320-326.

46. Metcalf & Eddy, *Suspended Growth Biological Treatment Processes*, in *Wastewater Engineering: Treatment and Reuse*. 2003, McGraw-Hill: New York. p. 659-886.

47. Metcalf & Eddy, *Attached Growth and Combined Biological Treatment Processes*, in *Wastewater Engineering: Treatment and Reuse*. 2003. p. 887-981.

48. Hood, A., M. Chopra, and M. Wanielista, *Assessment of Biosorption Activated Media Under Roadside Swales for the Removal of Phosphorus from Stormwater.* Water, 2013. **5**(1): p. 53-66.

49. Das, B.M., *Particle-Size Distribution Curve*, in *Principles of Geotechnical Engineering*. 2006, Cengage Learning: Stamford, CT. p. 37-43.

50. Das, B.M., *Sieve Analysis*, in *Soil Mechanics Laboratory Manual*. 2002, Oxford University Press: New York. p. 15-22.

51. Wanielista, M., T. Baldassari, P. Ryan, B. Rivera, T. Shah, and E. Stuart, *Feasibility Study of Waste Tire Use in Pollution Control for Stormwater Management, Drainfields,*

and Water Conservation in Florida. 2008, University of Central Florida Stormwater Management Academy: Orlando, FL.

52. Inglezakis, V.J. and S.G. Poulopoulos, *Basic Principles of Adsorption and Ion Exchange*, in *Adsorption, Ion Exchange and Catalysis - Design of Operations and Environmental Applications*. 2006, Elsevier: Amsterdam. p. 243-252.

53. Li, L. and A.P. Davis, *Urban Stormwater Runoff Nitrogen Composition and Fate in Bioretention Systems.* Environmental Science & Technology, 2014. **48**(6): p. 3403-3410.

54. Lekang, O.-I., *Chemical Removal of Ammonia*, in *Aquaculture Engineering*. 2007, Blackwell Publishing: Ames, Iowa. p. 129-130.

55. Namasivayam, C. and D. Sangeetha, *Equilibrium and kinetic studies of adsorption of phosphate onto ZnCl2 activated coir pith carbon.* Journal of Colloid and Interface Science, 2004. **280**(2): p. 359-365.

56. Boki, K., S. Tanada, T. Miyoshi, R. Yamasaki, N. Ohtani, and T. Tamura, *Phosphate removal by adsorption to activated carbon.* Nippon Eiseigaku Zasshi (Japanese Journal of Hygiene), 1987. **42**(3): p. 710-720.

57. Evangelou, V.P., *Sorption and Exchange Reactions*, in *Environmental Soil and Water Chemistry: Principles and Applications*. 1998, John Wiley & Sons: New York. p. 167-227.

58. Crittenden, J.C., R.R. Trussell, D.W. Hand, K.J. Howe, and G. Tchobanoglous, *Removal of Selected Constituents*, in *Water Treatment: Principles and Design*. 2005, John Wiley & Sons, Inc. p. 1553-1640.

59. Ozturk, N. and T.E. Bektas, *Nitrate removal from aqueous solution by adsorption onto various materials*, in *Journal of Hazardous Materials*. 2004. p. 155-162.

60. Das, B.M., *Clay Minerals*, in *Principles of Geotechnical Engineering*. 2006, Cengage Learning: Stamford, CT. p. 22-30.

61. Metcalf & Eddy, *Constituents in Wastewater*, in *Wastewater Engineering: Treatment and Reuse*. 2003, McGraw-Hill: New York. p. 27-152.

62. Douglas, G.B., M.S. Robb, D.N. Coad, and P.W. Ford, *A review of solid phase adsorbents for the removal of phosphorus from natural and waste waters*, in *Phosphorus in Environmental Engineering Technology: Principles and Applications*, E. Valsami-Jones, Editor. 2004, IWA Publishing: London, UK. p. 291-311.

63. Evangelou, V.P., *Organic Matter, Nitrogen, Phosphorus and Synthetic Organics*, in *Environmental Soil and Water Chemistry: Principles and Applications*. 1998, John Wiley & Sons: New York, NY. p. 323-363.

64. Barrer, R.M., *Clay minerals as selective and shape-selective sorbents.* Pure and Applied Chemistry, 1989. **61**(11): p. 1903-1912.

65. Xu, D., J. Xu, J. Wu, and A. Muhammad, *Studies on the phosphorus sorption capacity of substrates used in constructed wetland systems.* Chemosphere, 2006. **63**(2): p. 344-352.

66. American Public Health Association, A.W.W.A., ; Water Environment Federation, *4500-P PHOSPHORUS (2017)*, in *Standard Methods For the Examination of Water and Wastewater*, R.B.E. Baird, Andrew D.; Rice, Eugene W., Editor. 2017.

67. U.S. EPA, *Phosphorus*, in *Volunteer Stream Monitoring: A Methods Manual*. 1997, United States Environmental Protection Agency.

68. Labry, C., A. Youenou, D. Delmas, and P. Michelon, *Addressing the measurement of particulate organic and inorganic phosphorus in estuarine and coastal waters.* Continental Shelf Research, 2013. **60**: p. 28-37.

69. Karl, D.M. and K.M. Björkman, *Dynamics of dissolved organic phosphorus*, in *Biogeochemistry of marine dissolved organic matter*. 2015, Elsevier. p. 233-334.

70. Laboratory for Microbial Oceanography in the School of Ocean and Earth Science and Technology at the University of Hawaii at Manoa, *ORTHOPHOSPHATE AND DISSOLVED ORGANIC PHOSPHORUS*, in *Field & Laboratory Protocols*. 2019, University of Hawaii at Manoa.

71. Seufferheld, M.J. and M.J. Curzi, *Recent discoveries on the roles of polyphosphates in plants.* Plant molecular biology reporter, 2010. **28**(4): p. 549-559.

72. Ji, Z.-G., *Phosphorus*, in *Hydrodynamics and water quality: modeling rivers, lakes, and estuaries*. 2008, John Wiley & Gons: Hoboken, New Jersey. p. 299-302.

73. Wilhelm, J., J. Weitzman, P. Mayer, R. Walter, A. Keeley, and K. Forshay. *Soluble reactive phosphorus stream loads decrease following legacy sediment removal in a restored floodplain, Big Spring Run, PA*. in *AGU Fall Meeting Abstracts*. 2018. Washington, D.C.

74. Urbonas, B.R., *Design of a sand filter for stormwater quality enhancement.* Water Environment Research, 1999. **71**(1): p. 102-113.

75. Pitt, R., U. Khambhammettu, R. Andoh, L. Lemont, K. Osei, and S.E. Clark. *Laboratory and field tests of the Up-FloTM Filter*. in *Proceedings of the 11th International Conference on Urban Drainage, Edinburgh, Scotland, UK*. 2008.

76. Lenth, J., R. Dugopolski, M. Quigley, A. Poresky, and M. Leisenring, *Filterra Bioretention Systems: Technical Basis for High Flow Rate Treatment and Evaluation of Stormwater Quality Performance.* Prepared for Americast, Inc. September, 2010. **20**: p. 2010.

77. Domagalski, J.L. and H.M. Johnson, *Subsurface transport of orthophosphate in five agricultural watersheds, USA.* Journal of Hydrology, 2011. **409**(1-2): p. 157-171.

78. Mateus, D.M., M.M. Vaz, and H.J. Pinho, *Fragmented limestone wastes as a constructed wetland substrate for phosphorus removal.* Ecological Engineering, 2012. **41**: p. 65-69.

79. Zhe, Y., L. Chun, P. Jun-yu, C. Li-xiang, and Z. De-fang, *Study and Application of phosphorous removal Flocculants for Phosphorous Waste Water Treatment [J].* Guizhou Chemical Industry, 2008. **2**: p. 014.

80. Hussain, S., H.A. Aziz, M.H. Isa, A. Ahmad, J. Van Leeuwen, L. Zou, S. Beecham, and M. Umar, *Orthophosphate removal from domestic wastewater using limestone and granular activated carbon.* Desalination, 2011. **271**(1): p. 265-272.

81. Barrington, S., S. Kaoser, M. Shin, and J. Gélinas, *Precipitating swine manure phosphorus using fine limestone dust.* Canadian Biosystems Engineering, 2004. **46**: p. 6.1-6.6.

82. Larpkiattaworn, S., N. Pookerdsin, M. Wangchanachai, and P. Noophan, *Phosphorus Sorption Capacity of Concrete Waste, Natural Sorbents, Alum Residuals from Water Supply Sludge, and Ceramic Material for Tertiary Treatment in Onsite Systems.* EnvironmentAsia, 2013. **6**(1).

83. Sharifnia, S., M.A. Khadivi, T. Shojaeimehr, and Y. Shavisi, *Characterization, isotherm and kinetic studies for ammonium ion adsorption by light expanded clay aggregate (LECA).* Journal of Saudi Chemical Society, 2016. **20**(Supplement 1): p. S342-S351.

84. Wanielista, M., N.-B. Chang, A. Randall, M. Chopra, M. Hardin, J. Jones, A. Hood, and S. Salamah, *Demonstration Bio Media for Ultra-urban Stormwater Treatment*. 2014, FDOT.

85. Jones, J., N.-B. Chang, and M.P. Wanielista, *Reliability analysis of nutrient removal from stormwater runoff with green sorption media under varying influent conditions.* Science of the Total Environment, 2015. **502**: p. 434-447.

86. Wanielista, M., R. Kersten, and E. Ron, *Flow Routing*, in *Hydrology: Water Quantity and Quality Control*. 1997, John Wiley & Sons, Inc. p. 303-334.

87. Florida, S.M.A.a.t.U.o.C., *Best Management Practices for Stormwater Runoff: Designer and Review Manual*, F.D.o. Transportation, Editor. 2015, FDOT: Tallahasse, FL.

88. Makepeace, D.K., D.W. Smith, and S.J. Stanley, *Urban stormwater quality: Summary of contaminant data.* Critical Reviews in Environmental Science and Technology, 1995. **25**(2): p. 93-139.

89. U.S. EPA. *Recreational Water Quality Criteria Limits*. 2016; Available from: https://www.epa.gov/npdes/recreational-water-quality-criteria-limits.

90. U.S. EPA. *2012 Edition of the Drinking Water Standards and Health Advisories*. 2012; Available from: https://nepis.epa.gov/Exe/ZyPDF.cgi/P100N01H.PDF?Dockey=P100N01H.PDF.

91. Kaushik, R., R. Balasubramanian, and H. Dunstan, *Microbial quality and phylogenetic diversity of fresh rainwater and tropical freshwater reservoir.* PloS one, 2014. **9**(6): p. e100737.

92. New York State Department of Health. *Coliform Bacteria in Drinking Water Supplies*. 2017 [cited 2017; Available from: https://www.health.ny.gov/environmental/water/drinking/coliform_bacteria.htm.

93. Kurz, R.C., *Removal of microbial indicators from stormwater using sand filtration, wet detention, and alum treatment: best management practices*. 1998, Southwest Florida Water Management District.

94. U.S. EPA. *National Primary Drinking Water Regulations*. 2017 9/20/2017]; Available from: https://www.epa.gov/ground-water-and-drinking-water/national-primary-drinking-water-regulations#three.

95. Chong, M.N., J. Sidhu, R. Aryal, J. Tang, W. Gernjak, B. Escher, and S. Toze, *Urban stormwater harvesting and reuse: a probe into the chemical, toxicology and microbiological contaminants in water quality.* Environmental monitoring and assessment, 2013. **185**(8): p. 6645-6652.

96. Hamdan, S.M., *A literature based study of stormwater harvesting as a new water resource.* Water Science and Technology, 2009. **60**(5): p. 1327-1339.

97. Peng, J., Y. Cao, M.A. Rippy, A. Afrooz, and S.B. Grant, *Indicator and pathogen removal by low impact development best management practices.* Water, 2016. **8**(12): p. 600.

98. Clary, J., J. Jones, B. Urbonas, M. Quigley, E. Strecker, and T. Wagner, *Can stormwater BMPs remove bacteria? New findings from the international stormwater BMP database.* Stormwater Magazine May, 2008: p. 1-14.

99. Urbonas, B., *Assessment of stormwater BMPs and their technology.* Water Science and Technology, 1994. **29**(1-2): p. 347-353.

100. Chang, N.-B., M. Wanielista, A. Daranpob, Z. Xuan, and F. Hossain, *New performance-based passive septic tank underground drainfield for nutrient and pathogen removal using sorption media.* Environmental Engineering Science, 2010. **27**(6): p. 469-482.

101. Busscher, H.J., R.J.B. Dijkstra, E. Engels, D.E. Langworthy, D.I. Collias, D.W. Bjorkquist, M.D. Mitchell, and H.C. van der Mei, *Removal of Two Waterborne Pathogenic Bacterial Strains by Activated Carbon Particles Prior to and after Charge Modification.* Environmental Science & Technology, 2006. **40**(21): p. 6799-6804.

102. Pal, S., J. Joardar, and J.M. Song, *Removal of E. coli from Water Using Surface-Modified Activated Carbon Filter Media and Its Performance over an Extended Use.* Environmental Science & Technology, 2006. **40**(19): p. 6091-6097.

103. Stevik, T.K., G. Ausland, P.D. Jenssen, and R.L. Siegrist, *Removal of E. coli during intermittent filtration of wastewater effluent as affected by dosing rate and media type.* Water Research, 1999. **33**(9): p. 2088-2098.

104. Sawyer, C.N., P.L. McCarty, and G.F. Parkin, *Adsorption*, in *Chemistry for Environmental Engineering and Science, 5th ed.* 2003, McGraw-Hill: New York. p. 97-105.

105. Stewart, M.H., R.L. Wolfe, and E.G. Means, *Assessment of the bacteriological activity associated with granular activated carbon treatment of drinking water.* Applied and environmental microbiology, 1990. **56**(12): p. 3822-3829.

106. Powler, J.F. and R. Prasad, *Nitrogen*, in *Soil Fertility Management for Sustainable Agriculture*. 1997, CRC Press: Boca Raton. p. 115-163.

107. American Public Health Association, A.W.W.A., ; Water Environment Federation, *9215 Heterotrophic Plate Count*, in *Standard Methods for the Examination of Water and Wastewater*. 2004, American Public Health Association, American Water Works Association, & Water Environment Federation.

108. American Public Health Association, A.W.W.A., ; Water Environment Federation, *2540 Solids*, in *Standard Methods for the Examination of Water and Wastewater*. 2011, American Public Health Association, American Water Works Association, & Water Environment Federation.

109. Crittenden, J.C., R.R. Trussell, D.W. Hand, K.J. Howe, and G. Tchobanoglous, *Adsorption*, in *Water Treatment Principles and Design*. 2005, John Wiley & Sons: Hoboken, New Jersey. p. 1245-1357.

110. Cowen, W.F., K. Sirisinha, and G.F. Lee, *Nitrogen availability in urban runoff.* Journal (Water Pollution Control Federation), 1976. **48**(2): p. 339-345.

111. Kartal, B., L. van Niftrik, J.T. Keltjens, H.J.O. den Camp, and M.S. Jetten, *Anammox—growth physiology, cell biology, and metabolism*, in *Advances in microbial physiology*. 2012, Elsevier. p. 211-262.

112. Ryan, P., M. Wanielista, and N.-B. Chang, *Nutrient reduction in stormwater pond discharge using a chamber upflow filter and skimmer (CUFS).* Water, Air, and Soil Pollution, 2010. **208**(1-4): p. 385-399.

113. Brading, M.G., J. Jass, and H.M. Lappin-Scott, *Dynamics of Bacterial Biofilm Formation*, in *Microbial Biofilms*, H.M. Lappin-Scott and J.W. Costerton, Editors. 1995, Cambridge Universtiy Press: Cambridge. p. 46-63.

114. Howell, J. and B. Atkinson, *Sloughing of microbial film in trickling filters.* Water Research, 1976. **10**(4): p. 307-315.

115. Jansen, J. and G. Kristensen, *Fixed film kinetics: Denitrification in fixed films.* Department of Sanitary Tech., Univ. Denmark, 1980: p. 80-59.

116. Star, W.R.L.v.d., W.R. Abma, D. Blommers, J.-W. Mulder, T. Tokutomi, M. Strous, C. Picioreanu, and M.C.M.v. Loosdrecht, *Startup of reactors for anoxic ammonium oxidatioin: Experiences from the first full-scale anammox reactor in Rotterdam.* Water Research, 2007. **41**(18): p. 4149-4163.

117. Applegate, D.H. and J.D. Bryers, *Effects of carbon and oxygen limitations and calcium concentrations on biofilm removal processes.* Biotechnology and bioengineering, 1991. **37**(1): p. 17-25.

118. Metcalf & Eddy, *Introduction to Process Analysis and Selection*, in *Wastewater Engineering: Treatment and Reuse*. 2003. p. 215-310.

119. Sigma-Aldrich, *Safety Data Sheet: 2-Imidazolidinethione*. 2019, Sigma-Aldrich.

120. Reddy, K.R. and R.D. DeLaune, *Nitrogen*, in *Biogeochemistry of wetlands: science and applications*. 2008, CRC press: New York. p. 257-323.

121. Munch, J.C. and G.L. Velthof, *Denitrification and Agriculture,* in *Biology of the Nitrogen Cycle,* H. Bothe, S.J. Ferguson, and W.E. Newton, Editors. 2007, Elsevier: New York. p. 331-341.

122. Yao, K.-M., M.T. Habibian, and C.R. O'Melia, *Water and waste water filtration. Concepts and applications.* Environmental science & technology, 1971. **5**(11): p. 1105-1112.

123. Kannan, N. and M.M. Sundaram, *Kinetics and mechanism of removal of methylene blue by adsorption on various carbons—a comparative study.* Dyes and pigments, 2001. **51**(1): p. 25-40.

124. Jagadamma, S., M.A. Mayes, and J.R. Phillips, *Selective sorption of dissolved organic carbon compounds by temperate soils.* PloS one, 2012. **7**(11): p. e50434.

125. Roberts, P.V. and R.S. Summers, *Performance of granular activated carbon for total organic carbon removal.* Journal-American Water Works Association, 1982. **74**(2): p. 113-118.

126. Alamo-Nole, L., O. Perales-Perez, and F.R. Roman, *Use of recycled tires crumb rubber to remove organic contaminants from aqueous and gaseous phases.* Desalination and Water Treatment, 2012. **49**(1-3): p. 296-306.

127. Wang, L.K. and N.K. Shammas, *Single-Sludge Biological Systems for Nutrients Removal*, in *Advanced Biological Treatment Processes*, Y.-T. Hung, Editor. 2009, Humana Press, a part of Springer Science & Business Media. p. 209-270.

128. Chen, G., H. Ozaki, and Y. Terashima, *Endogenous denitrification in biofilm.* Water Science and Technology, 1992. **26**(3-4): p. 523-534.

129. Jetten, M.S., M. Strous, K.T. Van de Pas-Schoonen, J. Schalk, U.G. van Dongen, A.A. van de Graaf, S. Logemann, G. Muyzer, M.C. van Loosdrecht, and J.G. Kuenen, *The anaerobic oxidation of ammonium.* FEMS Microbiology reviews, 1998. **22**(5): p. 421-437.

130. Thieman, W.J. and M.A. Palladino, *History of Genetic Manipulation: Recominant DNA Technology*, in *Introduction to Biotechnology*. 2004, Pearson-Benjamin Cummings: San Francisco. p. 51-84.

131. Jensen, M.M., P. Lam, N.P. Revsbech, B. Nagel, B. Gaye, M.S. Jetten, and M.M. Kuypers, *Intensive nitrogen loss over the Omani Shelf due to anammox coupled with dissimilatory nitrite reduction to ammonium.* The ISME journal, 2011. **5**(10): p. 1660.

132. Trimmer, M. and P. Engström, *Distribution, activity, and ecology of anammox bacteria in aquatic environments*, in *Nitrification*, B.B. Ward, D.J. Arp, and M.G. Klotz, Editors. 2011, American Society of Microbiology: Washington, D.C. p. 201-235.

133. Mohan, S.B. and J.A. Cole, *The dissimilatory reduction of nitrate to ammonia by anaerobic bacteria*, in *Biology of the nitrogen cycle*, H. Bothe, S.J. Ferguson, and W.E. Newton, Editors. 2007, Elsevier: Amsterdam. p. 93-106.

134. Putz, M., P. Schleusner, T. Rütting, and S. Hallin, *Relative abundance of denitrifying and DNRA bacteria and their activity determine nitrogen retention or loss in agricultural soil.* Soil Biology and Biochemistry, 2018. **123**: p. 97-104.

135. Kraft, B., M. Strous, and H.E. Tegetmeyer, *Microbial nitrate respiration–genes, enzymes and environmental distribution.* Journal of biotechnology, 2011. **155**(1): p. 104-117.

136. Cameron, S.G. and L.A. Schipper, *Nitrate removal and hydraulic performance of organic carbon for use in denitrification beds.* Ecological Engineering, 2010. **36**(11): p. 1588-1595.

137. Healy, M.G., T.G. Ibrahim, G.J. Lanigan, A.J. Serrenho, and O. Fenton, *Nitrate removal rate, efficiency and pollution swapping potential of different organic carbon media in laboratory denitrification bioreactors.* Ecological Engineering, 2012. **40**: p. 198-209.

138. Das, B.M., *Engineering Classification of Soil*, in *Principals of Geotechnical Engineering*, P. Daly, Editor. 2006, Cengage Learning: Stamford, CT. p. 90-105.

139. Tchobanoglous, G., F.L. Burton, and H.D. Stensel, *Constituents in Wastewater*, in *Wastewater Engineering: Treatment and Reuse*. 2003, McGraw-Hill: New York, NY. p. 27-151.